Status and recent results of the MAGIC telescope system

Christian Fruck for the MAGIC Collaboration

MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescopes

MAX-PLANCK-GESELLSCHAFT

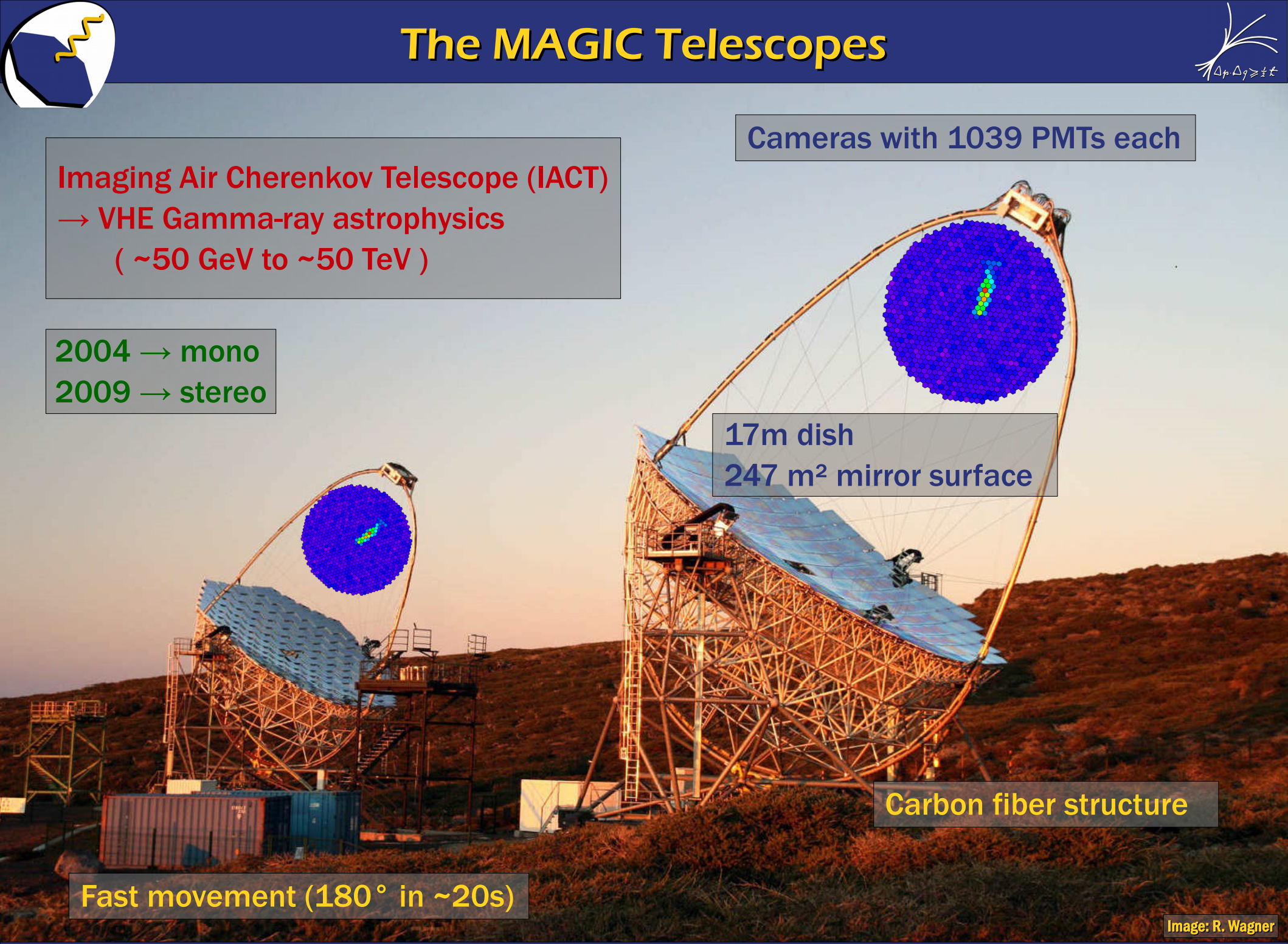
Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

The MAGIC Telescopes

Imaging Air Cherenkov Telescope (IACT)
→ VHE Gamma-ray astrophysics
(~50 GeV to ~50 TeV)

2004 → mono
2009 → stereo

Cameras with 1039 PMTs each



17m dish
247 m² mirror surface

Carbon fiber structure

Fast movement (180° in ~20s)

Image: R. Wagner

The MAGIC Telescopes on La Palma

Site:

Observatorio del
Roque de los Muchachos,
2200m a.s.l.

La Palma,
Canary islands, Spain

The MAGIC Collaboration

~160 Collaboration members in 10 countries

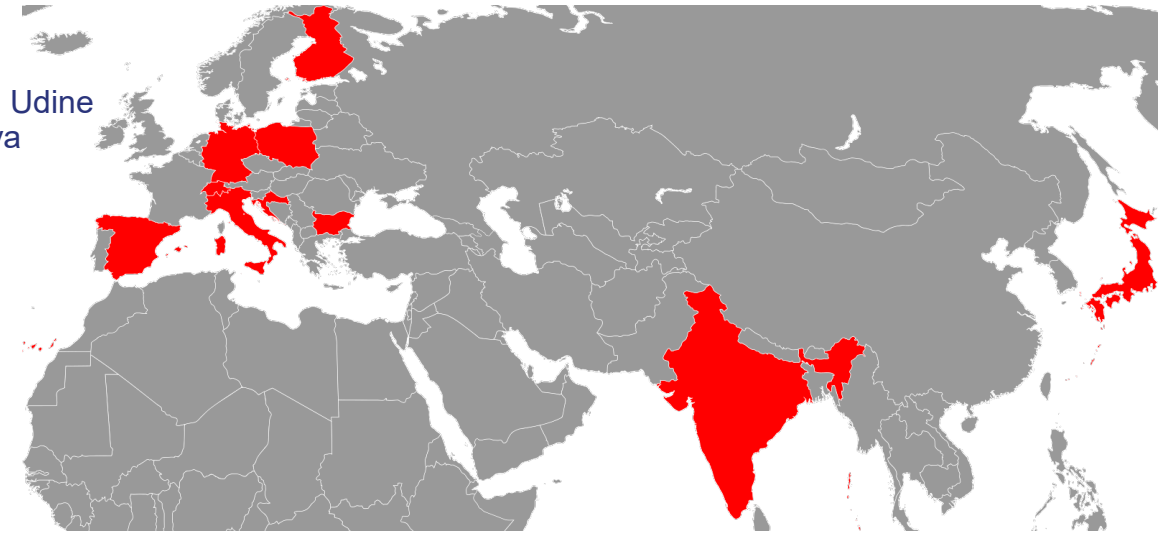
Germany:
Max-Planck-Institut für Physik, München
Technische Universität Dortmund, Dortmund
Deutsches Elektronen-Synchrotron (DESY) Zeuthen, Zeuthen
Universität Würzburg, Würzburg

Finnland:
Finnish MAGIC Consortium:
Tuorla Observatory, University of Turku,
University of Oulu, Finland, Piikkiö

Switzerland:
ETH Zurich, Institute for Particle Physics, Zurich

Italy:
Università dell'Insubria and INFN Milano Bicocca, Como
Universita di Pisa , and INFN Pisa, Pisa
INAF - National Institute for Astrophysics, Roma
Università di Siena and INFN sez. di Pisa, Siena
Università di Udine and INFN, sezione di Trieste, Italy, Udine
Università di Padova and INFN sez. di Padova, Padova

Poland:
Division of Astrophysics, University of Lodz, Lodz



Croatia:
Croatian MAGIC Consortium:
Institute R. Boskovic,
University of Rijeka,
University of Split,
University of Zagreb-FER, Zagreb

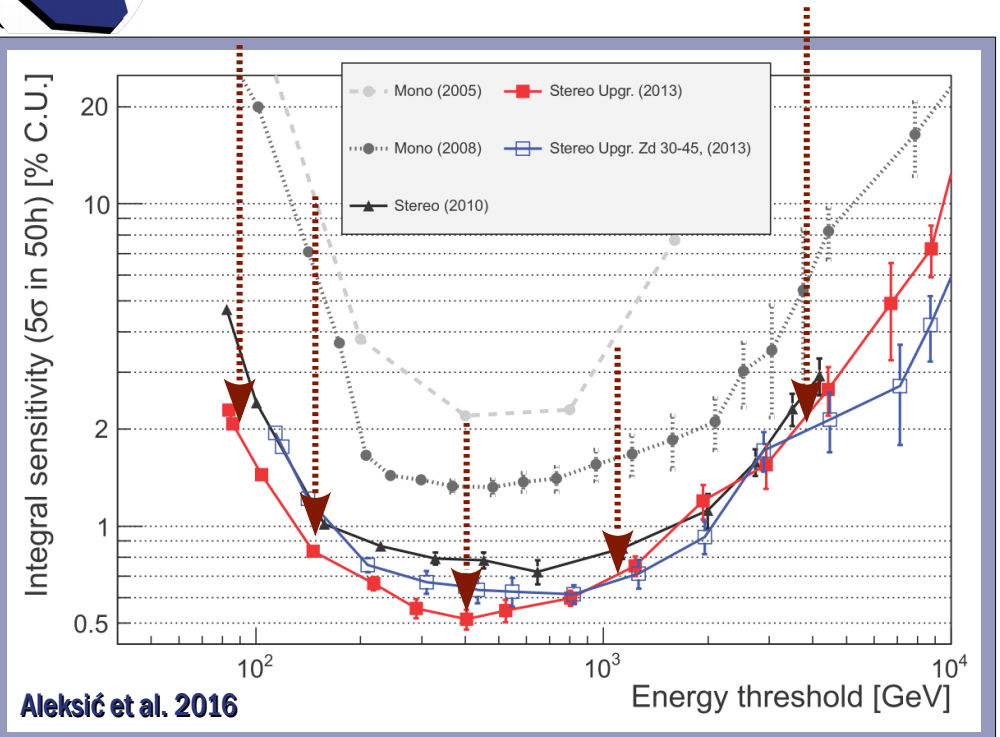
Bulgaria:
Institute for Nuclear Research and Nuclear Energy, Sofia

Spain:
Universitat Autònoma de Barcelona, Barcelona
Universitat de Barcelona, Barcelona, Spain
Institut de Ciencies de l'Espai (IEEC-CSIC), Bellaterra
Institut de Fisica d'Altes Energies (IFAE)
Instituto de Astrofisica de Canaria, La Laguna (Tenerife)
Universidad Complutense, Madrid, Madrid
CIEMAT, Madrid

Japan:
Japanese
MAGIC Consortium:
Kyoto, Tokyo

India:
Saha Institute of Nuclear Physics, Kolkata

Performance and upgrades



Aleksić et al. 2016

Key performance parameters:

- Integral sensitivity above 220 GeV:
  0.66% of Crab Nebula flux in 50h
- Angular resolution:
  0.1 deg – 0.05 deg
- Energy resolution:
  15-24%
- All performance parameters in:

Aleksić et al. 2016, Aph, 72, 76

Upgrade history:

2007: new faster readout for MAGIC-I

2009: MAGIC-II built, stereo operations

2011-2012: upgrade of both readout systems and new camera for MAGIC-I

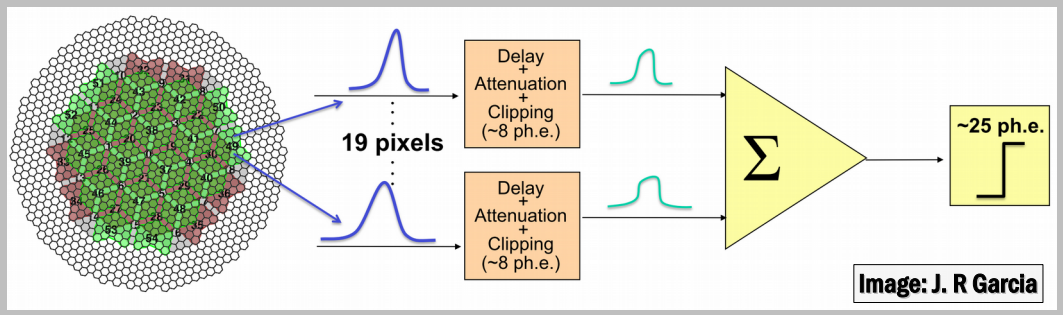
Aleksić et al. 2016, Aph, 72, 61

Upgrades lead by MPP scientists

New technological developments

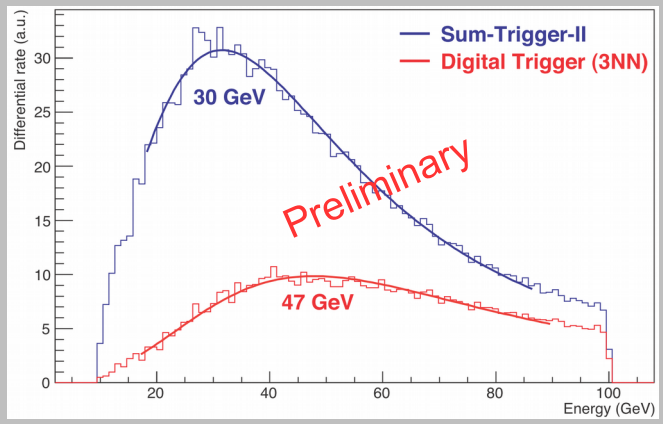
The analog Sum Trigger II:

J. Rodriguez Garcia
T 18.4 (Today 11:50)



MC studies:
~40 lower trigger energy Threshold

→ ~30Gev

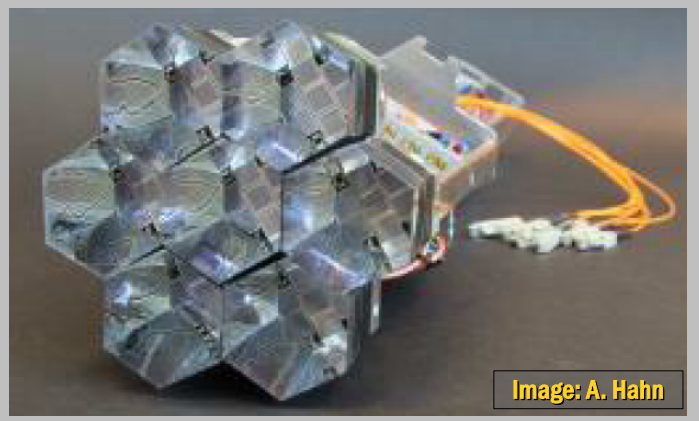


Tests of SiPM clusters in the MAGIC camera:

C. Jung
T 65.2 (Tue. 17:05)

technische universität dortmund

MPP prototype cluster:



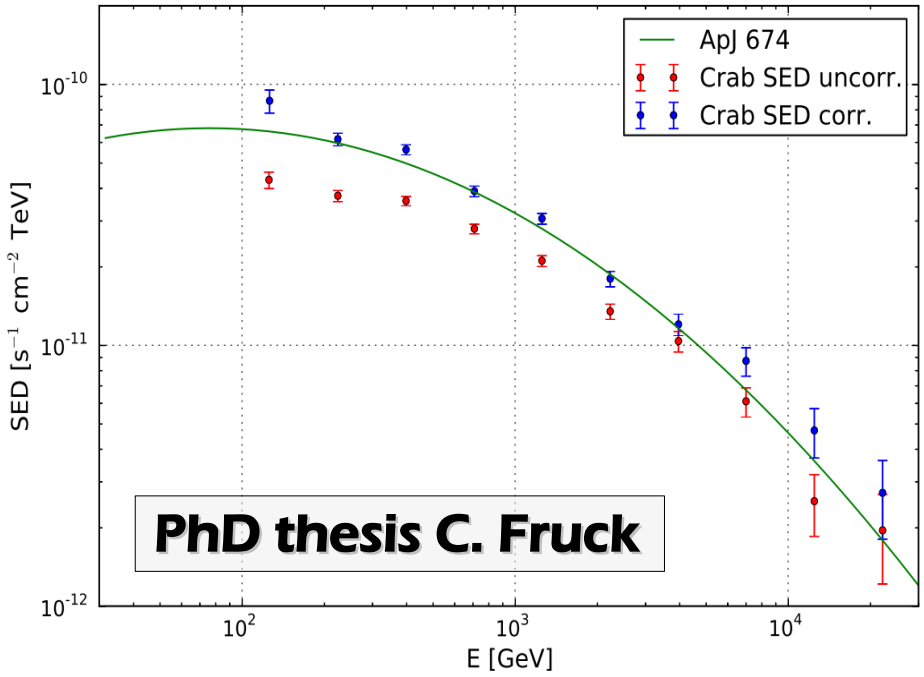
Correcting data with LIDAR measurements

D. Müller
T 38.8 (Today 17:00)

MAGIC micro LIDAR system and data corrections:

- Measuring transmission in obs. dir.
- Correcting energy and est. Aeff
- Increased effective duty cycle

→ **MAGIC is first IACT correcting Spectra/SEDs based on LIDAR data**



Corrections applied to part of data in two publications:

Mrk501 MWL campaign (Furniss et al, ApJ, 812 (2015) 65)
V339 Del nova outburst (Ahnen et al. A&A, (2015), 582, A67)

More about atmospheric monitoring:

M. Will
T 80.3 (Wed. 17:00)

The main scientific targets of MAGIC

Galactic Physics:
PWN, SNR, Binaries,
Pulsars, Galactic Center

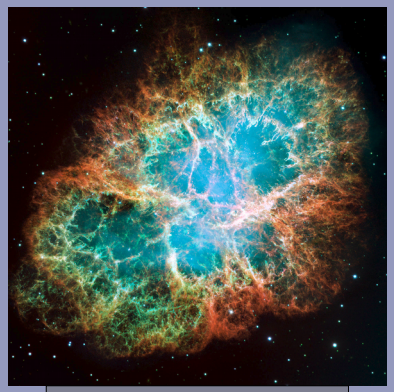


Image source: NASA/ESA

AGN Physics:
BL Lacs, FSRQs, Radio galaxies

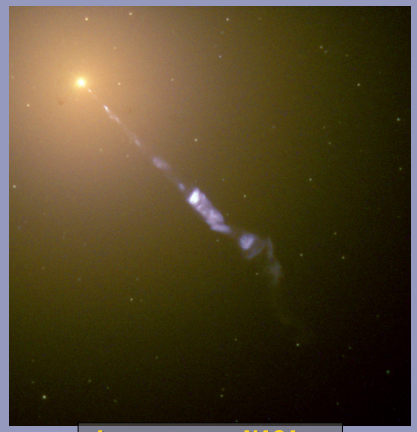


Image source: NASA

Fundamental Physics & Cosmology:
Dark matter, LIV,
EBL, IGMF & cosmology

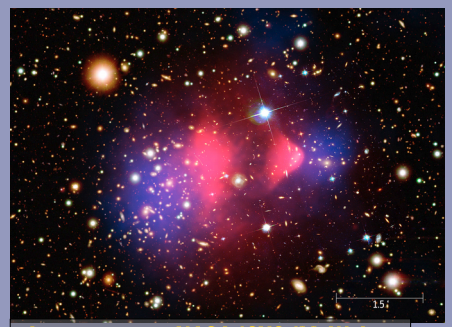


Image source: NASA/CXC/M. Weiss

Gamma Ray Bursts:

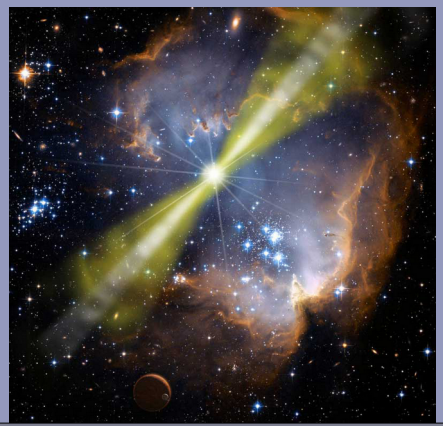
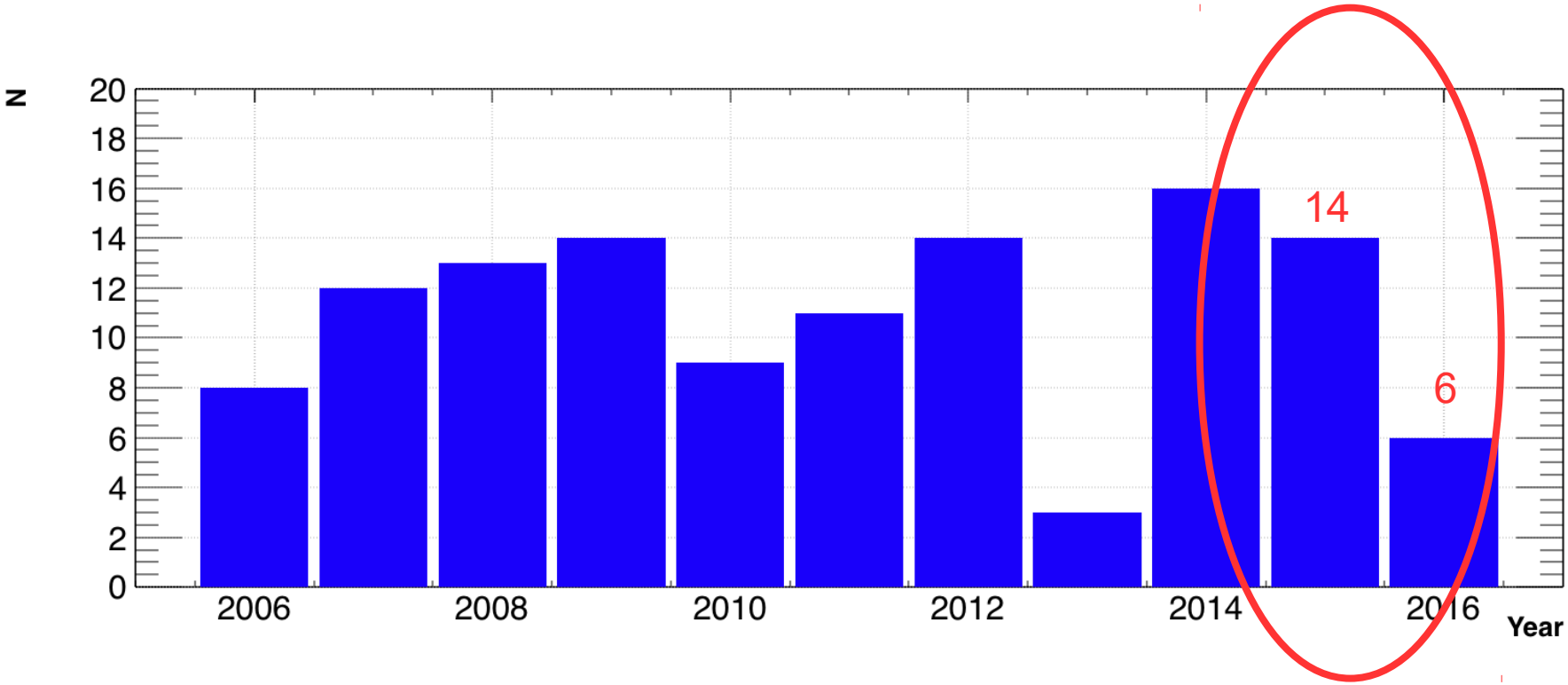


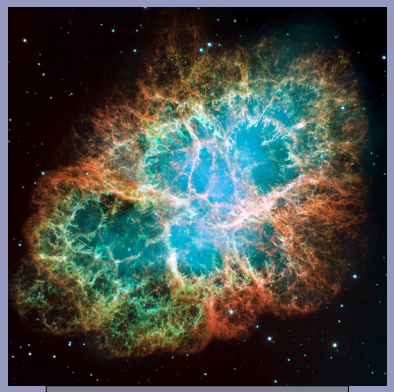
Image source: NASA/Swift/Mary Pat Hrybyk-Keith and John Jones

Peer reviewed publications by year



The main scientific targets of MAGIC

Galactic Physics:
PWN, SNR, Binaries,
Pulsars, Galactic Center



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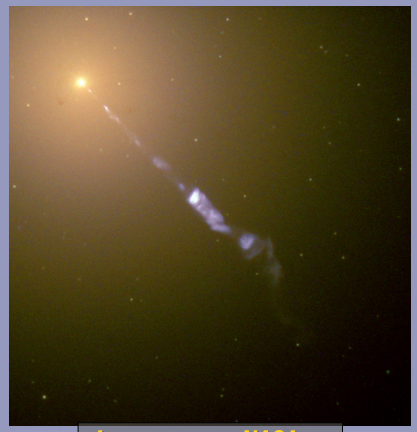

Image source: NASA

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Dark matter, LIV,
EBL, IGMF & cosmology

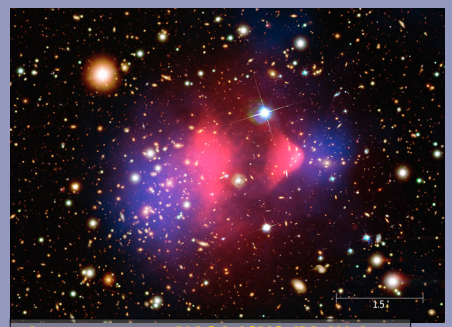


Image source: NASA/CXC/M. Weiss

Gamma Ray Bursts:

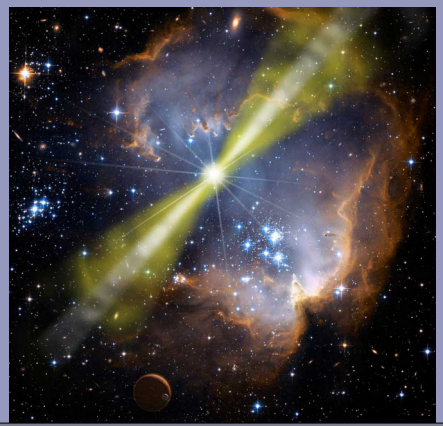


Image source: NASA/Swift/Mary Pat Hrybyk-Keith and John Jones

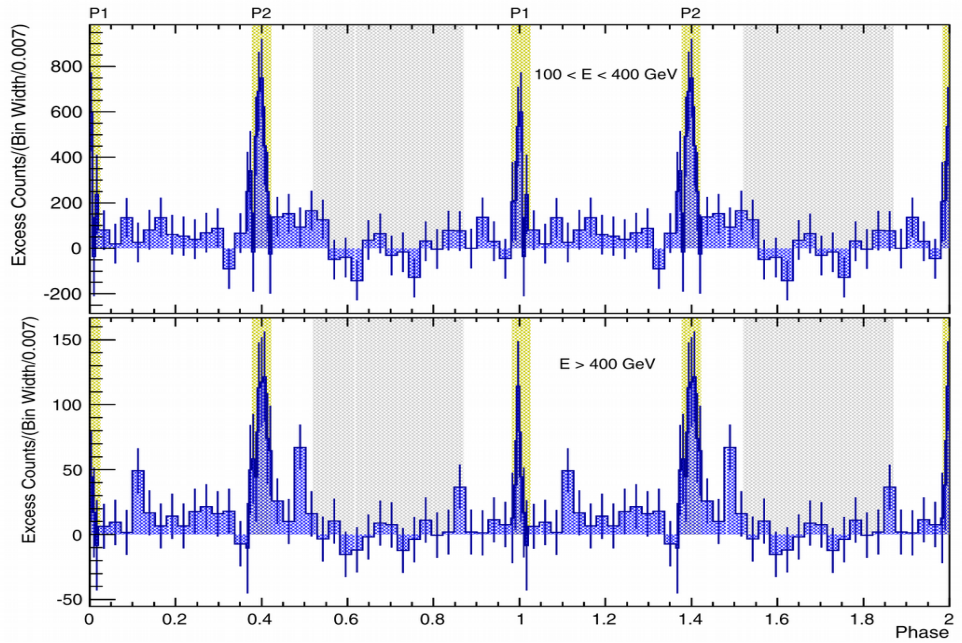
Galactic Highlights

Image source: ESO

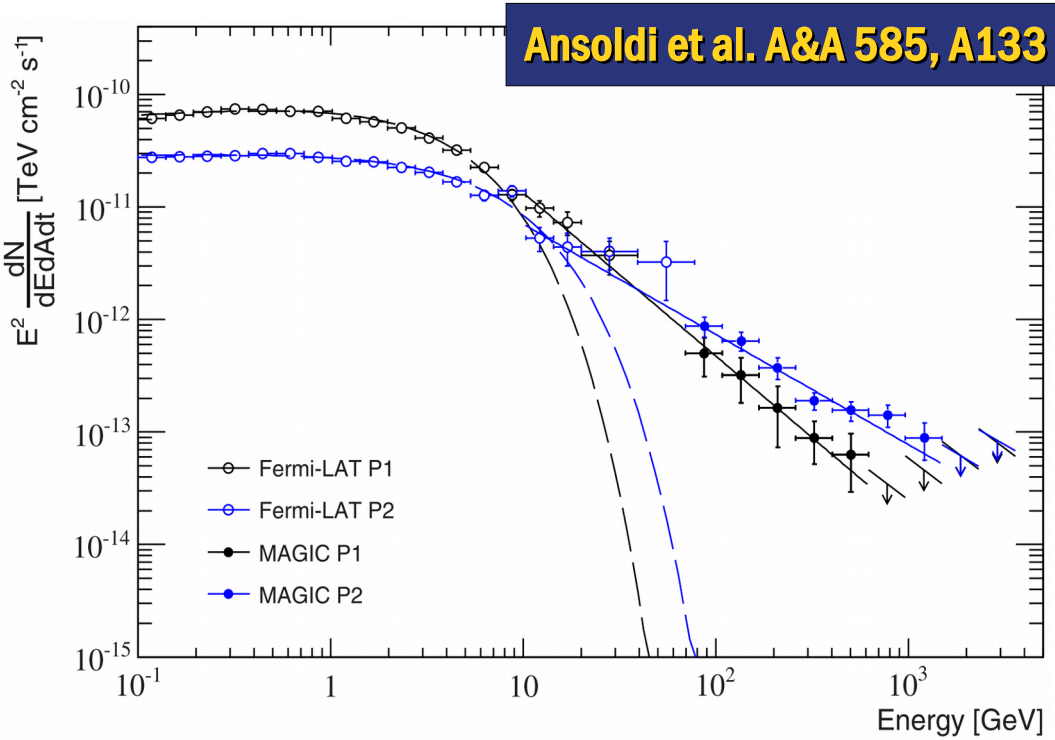
TeV emission from the Crab Pulsar

- **Unprecedented observations of PL component in pulsed emission by MAGIC extending up to 2TeV**
- **Challenging model predictions (IC scattering component needed)**

J. Rodriguez Garcia
T 18.4 (Today 11:50)

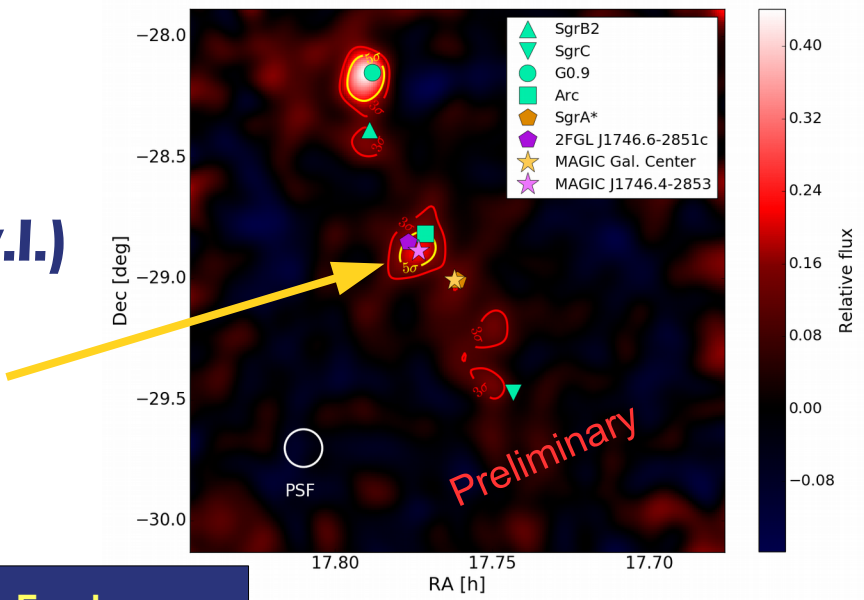


Ansoldi et al. A&A 585, A133 (2016)



Galactic Center

- Observed by MAGIC 2012/13/14/15
- Triggered by pericenter passage of G2
- No variability in TeV (also not in other w.l.)
- Discovered new source of VHE Gamma radiation coincident with GC Arc



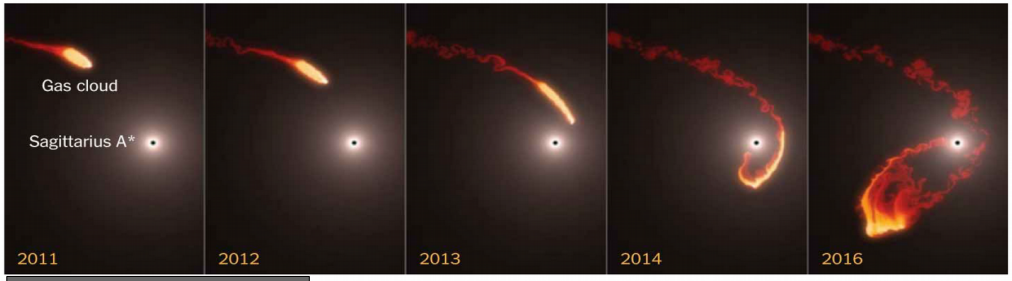
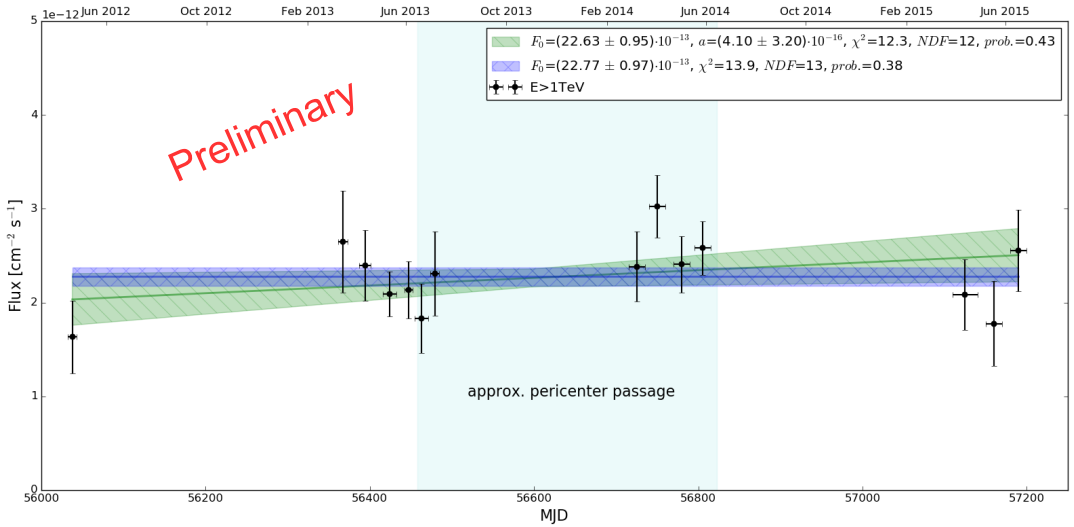
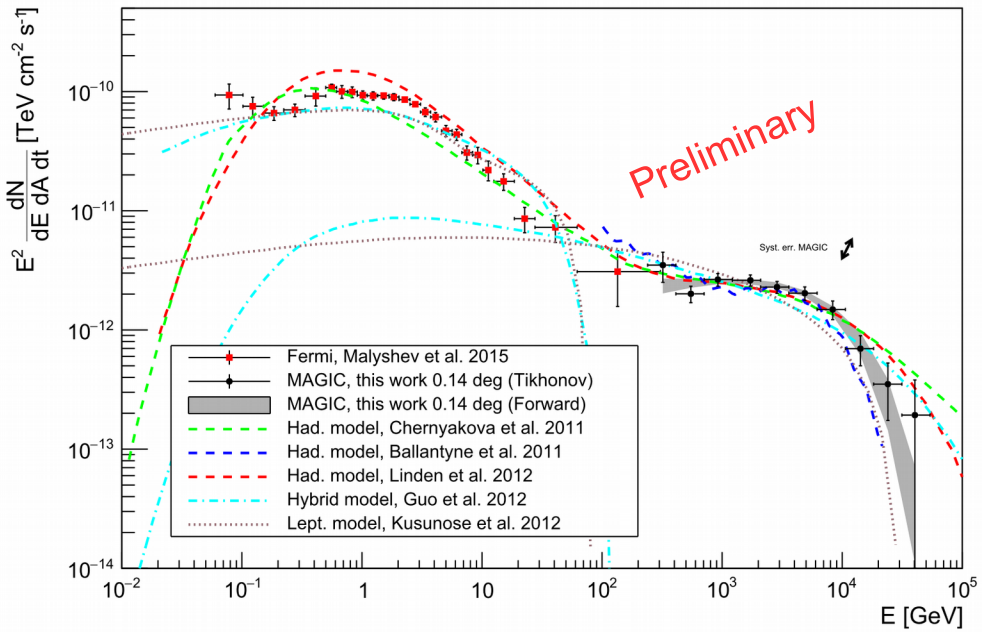


Image source: ESO

C. Fruck
T 80.8 (Wed. 18:35)

PhD thesis C. Fruck

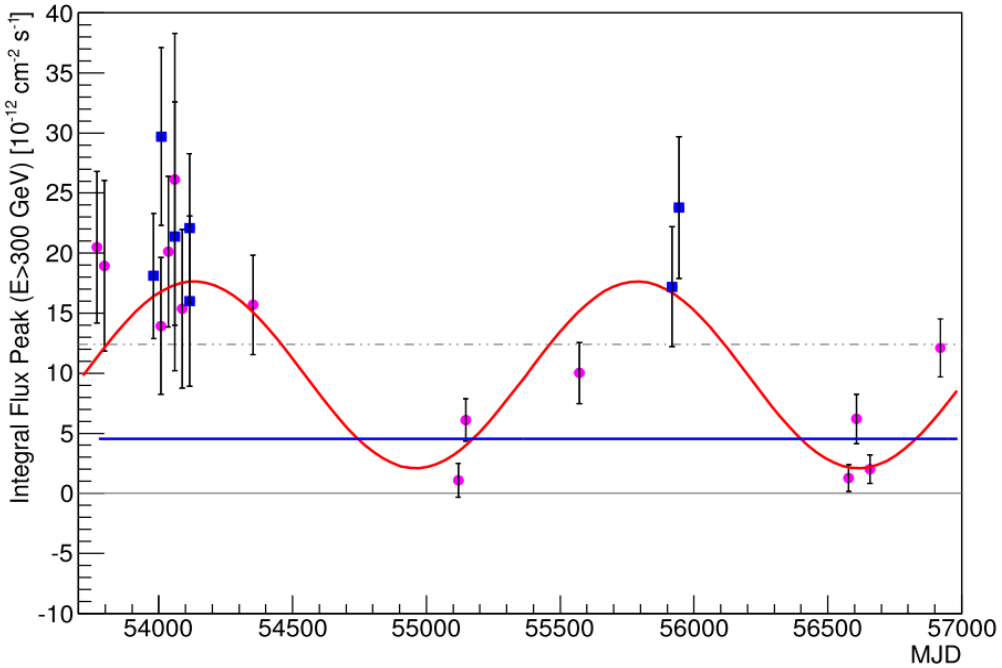


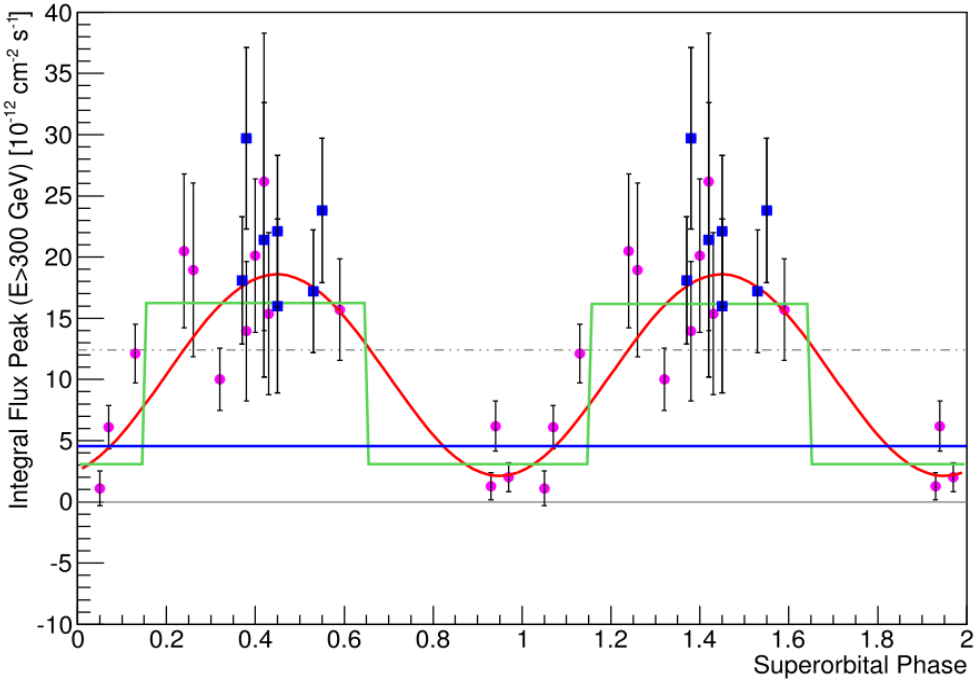


Superorbital variability of LS I +61 303

- Binary system of Be star and compact obj. (Period of 26.5 d)
- First detected in VHE by MAGIC in 2006 (Albert et al. 2006)
- Observed 2010 – 2014 and archival data (MAGIC, VERITAS)
- Superorbital period (1655 +- 65) d
- Consistent with radio (1667 d)

Ahnen et al. (2015), submitted to A&A





AGN Highlights

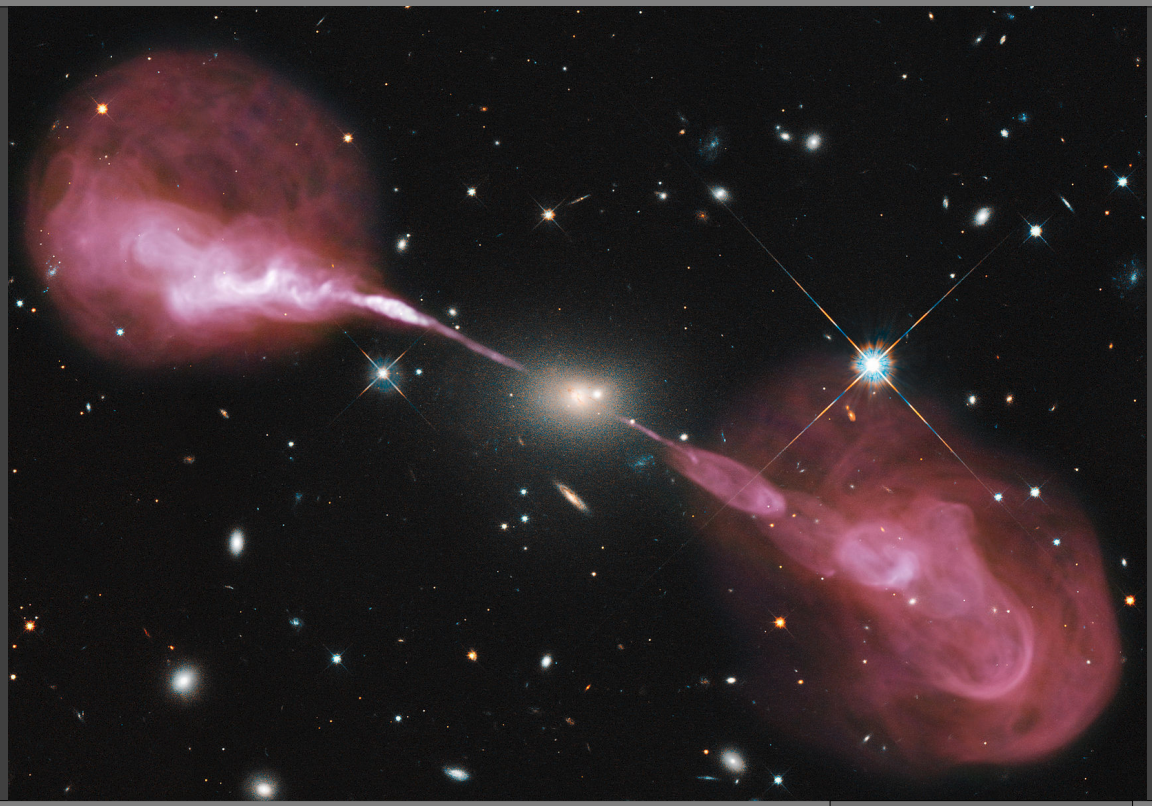
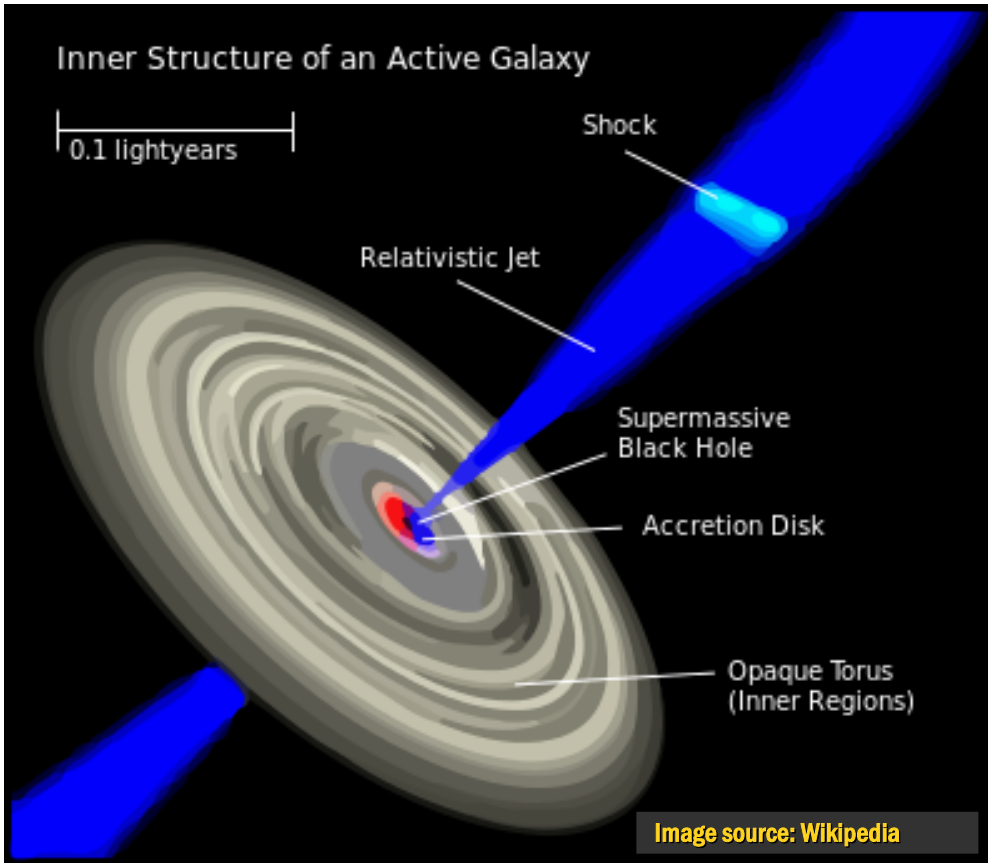
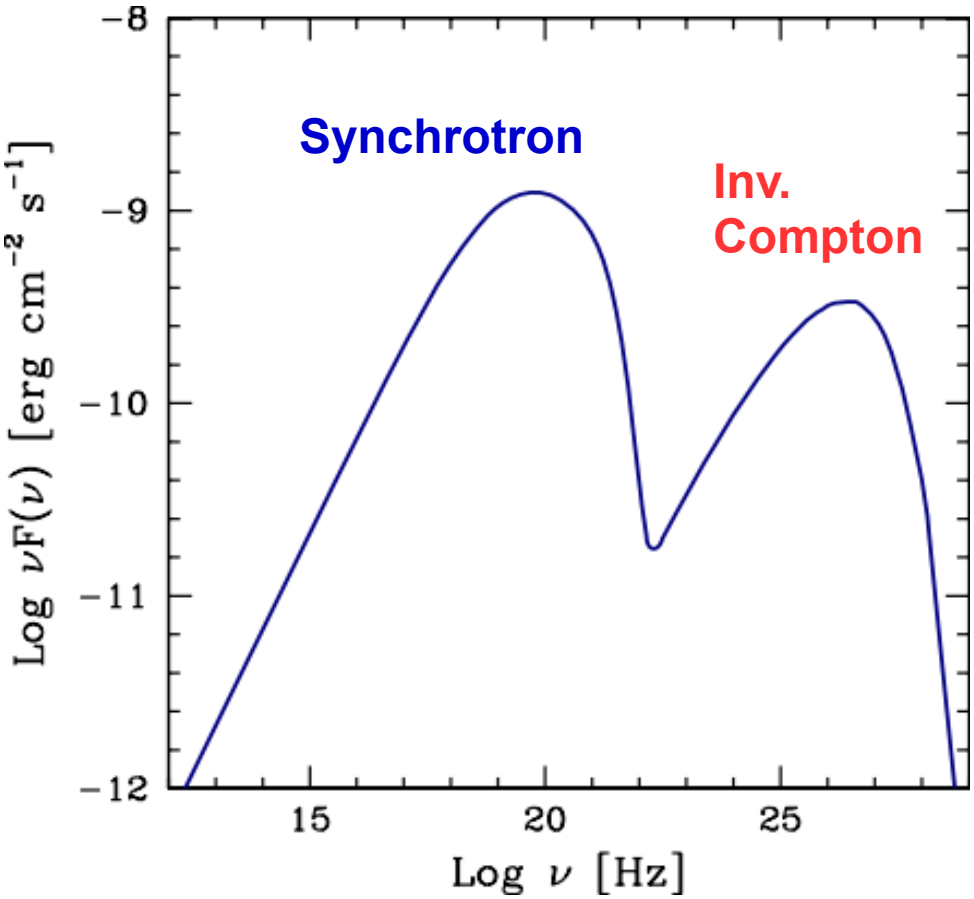


Image source: NASA/ESA

Active Galactic Nuclei (AGN)

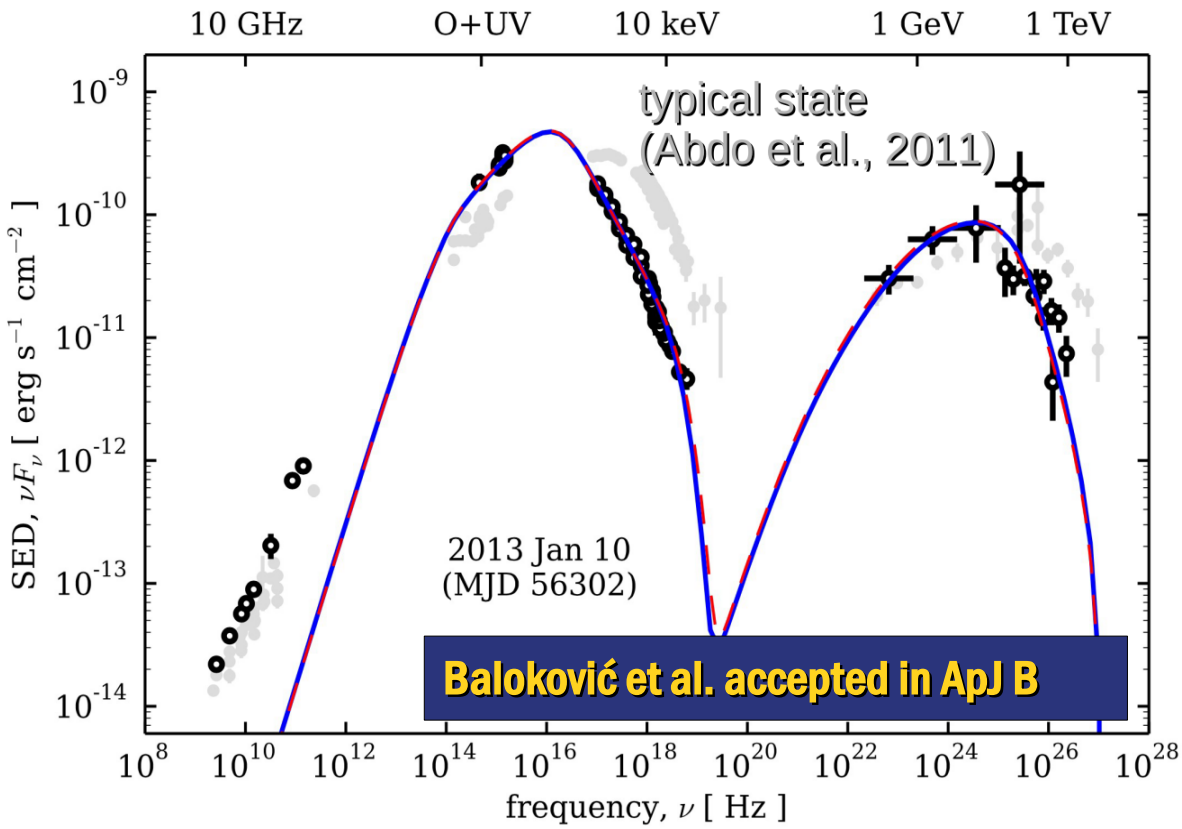
- Super Massive Black Hole (SMBH) with accretion disk and jet (can be Mpc)
- Classification depending on viewing angle and accretion rate
- most luminous objects in the Universe, especially in VHE Gamma rays
- Emitting over the whole EM spectrum (Typically showing two bump SED)





Bright Blazar in low state – Mrk 421(2013)

- Nearby (130 Mpc) high-peaked BL Lac type Blazar
- Observations: MWL campaign with NuSTAR, VERITAS and others in 2013 (very low emission state)
- Synchrotron and IC peaks shifted towards low energy
- Simultaneous hour scale variability in X-ray and VHE
- Modeling: Multiple compact regions with in situ electron acceleration



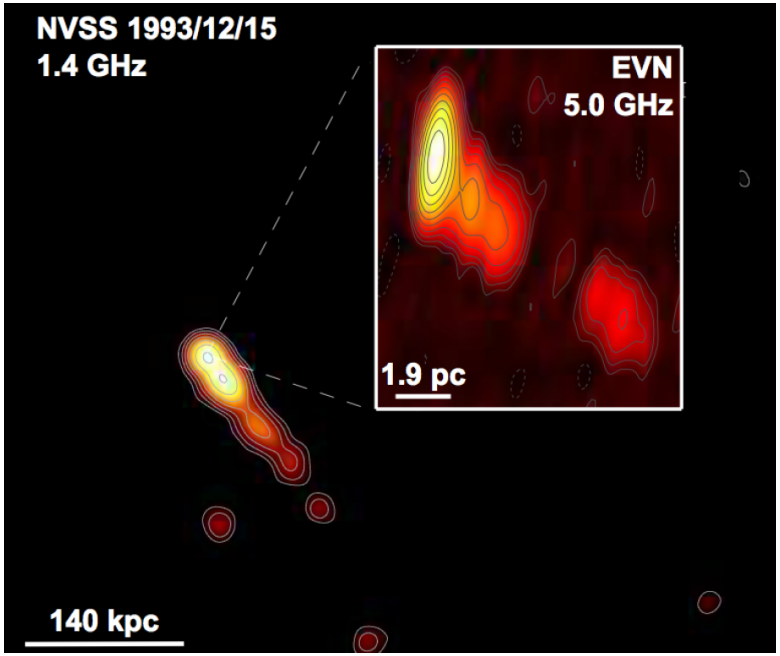
More on Mrks:

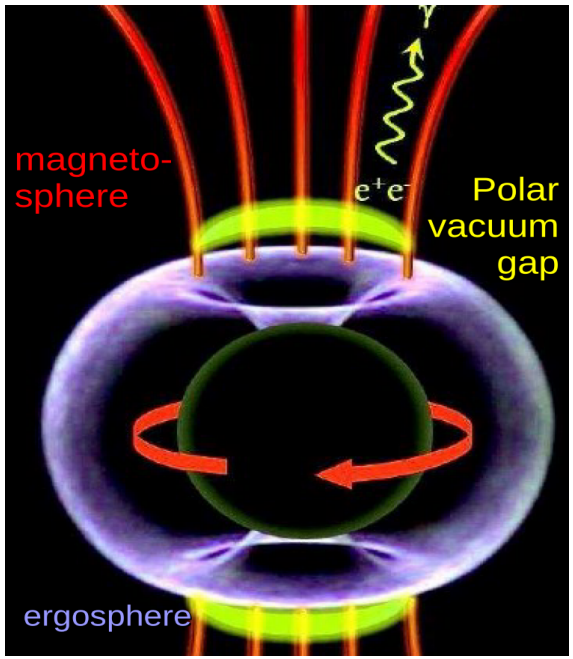
M. Doert T 104.1 (Do 16:45)

K. Ishio T 104.4 (Do 17:30)

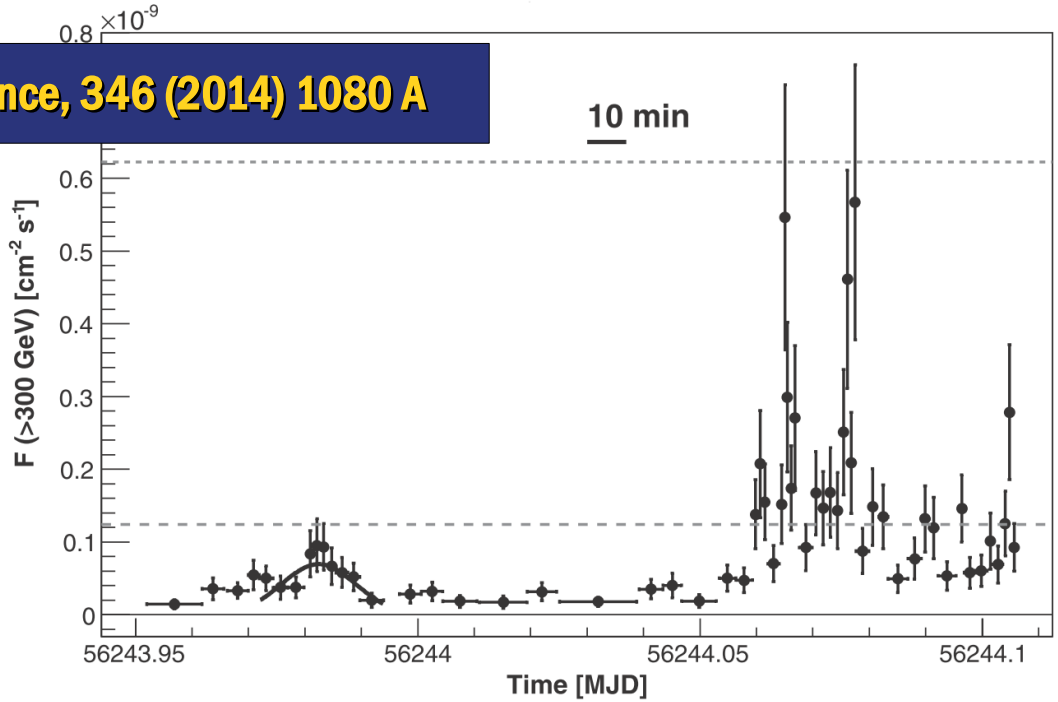
Black Hole Lightning in IC310

- Misaligned Blazar / Radio Galaxy in Perseus Cluster
- Minute scale variability during flare in 2012
- Misalignment (>10 deg)
  => Doppler factor (< 4)
- Causality: size of emission region of sub event horizon scale
- Magnetospheric emission of VHE Gamma-rays favored





Aleksić et al., Science, 346 (2014) 1080 A



FSRQ PKS 1441+25 at redshift z = 0.940

- Most luminous type of AGN
- Only 6(5) detected in VHE Gamma-rays 5(4) detected by MAGIC
- PKS 1441+25 Observed and detected by MAGIC in April 2015 (following up Fermi)

ATel #7416, Razmik Mirzoyan

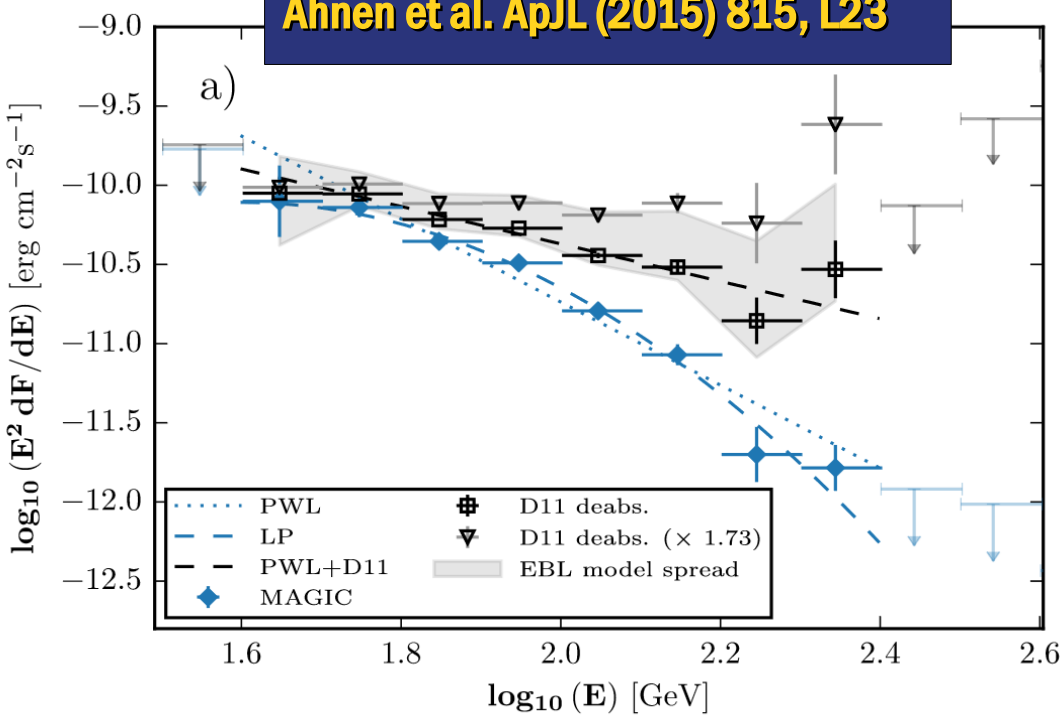
- Most distant VHE known source together with QSO B0218+357 (z = 0.944)

ATel #6349, Razmik Mirzoyan

- Lack of absorption features in the GeV range → external Compton scenario

Source	Redshift	Discovery	Year
3C 279	0.5362	MAGIC	2006
PKS1510-089	0.361	H.E.S.S.	2009
PKS 1222+216 (4C + 21.35)	0.432	MAGIC	2010
B 0218+357	0.944	MAGIC	2014
PKS 1441+25	0.939	MAGIC	2015
S4 0954+65* (class. debate)	>0.368	MAGIC	2015

Ahnen et al. ApJL (2015) 815, L23



Fundamental physics an Cosmology

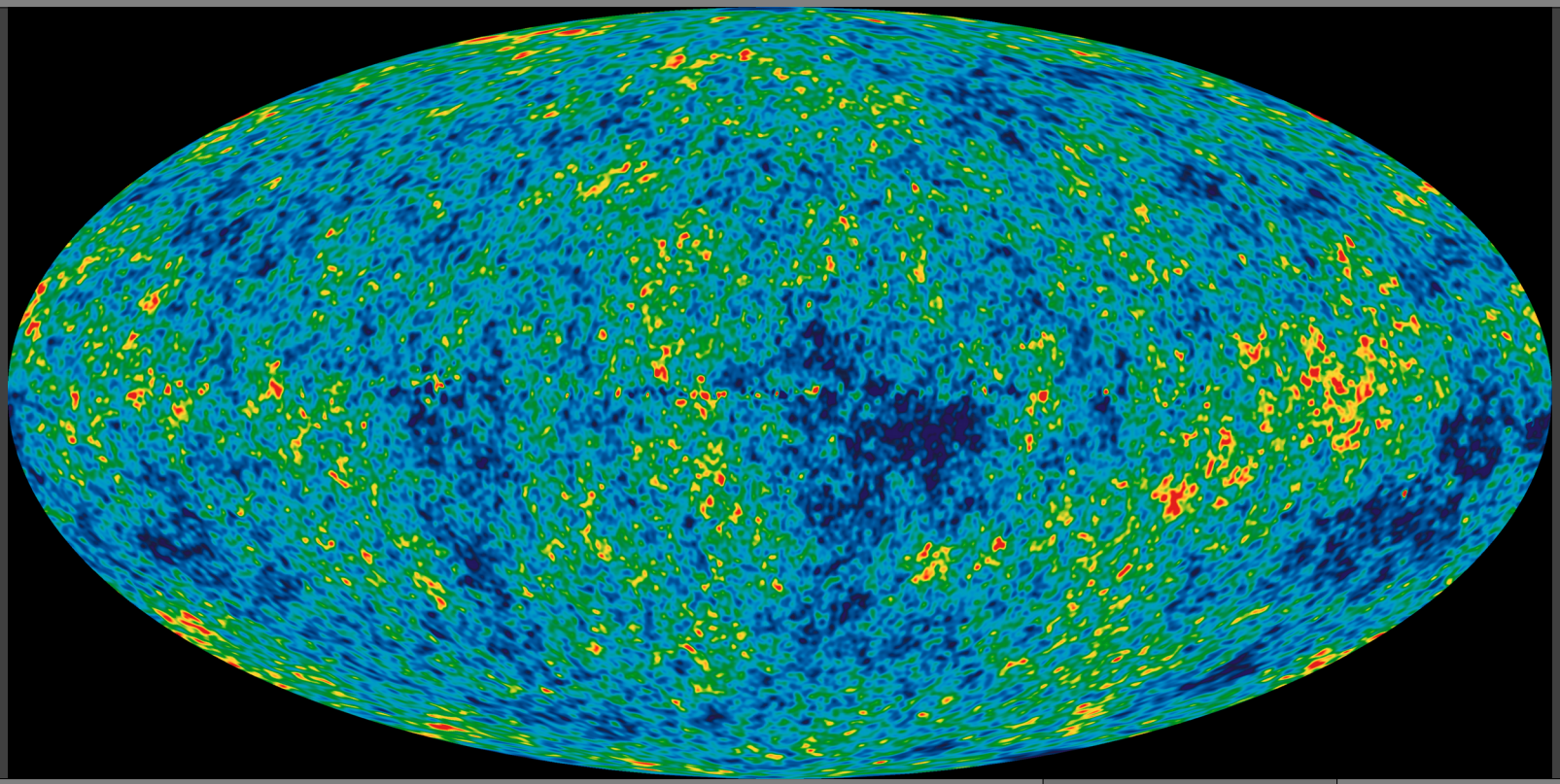
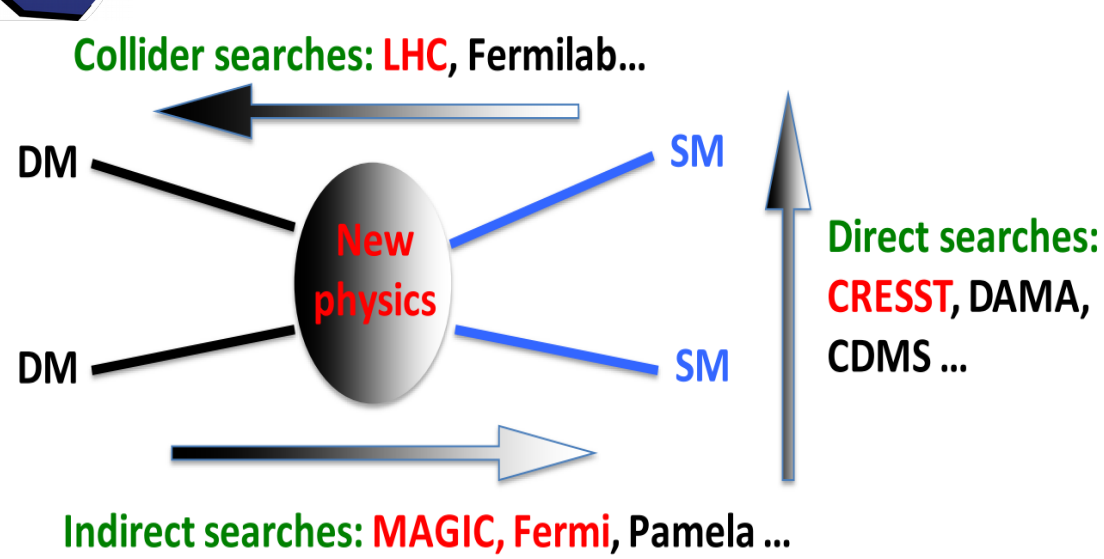
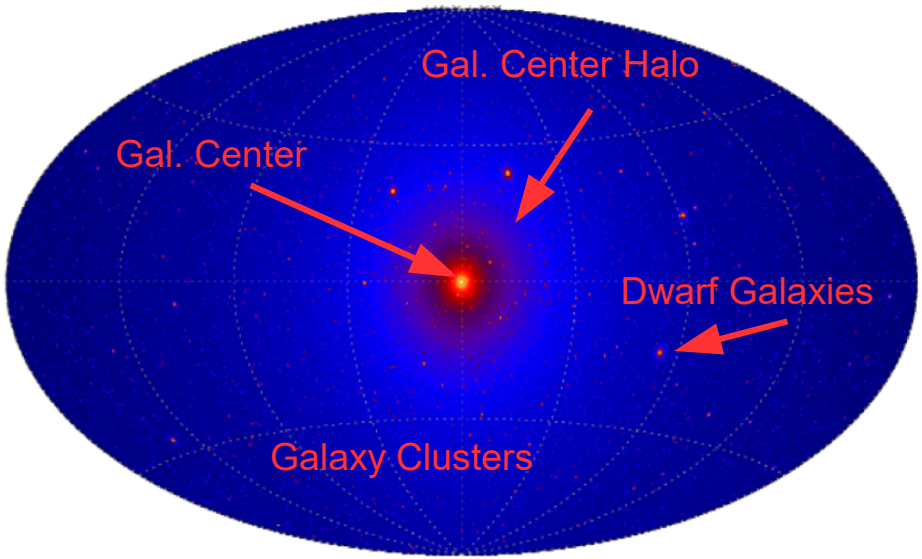


Image source: Wikipedia

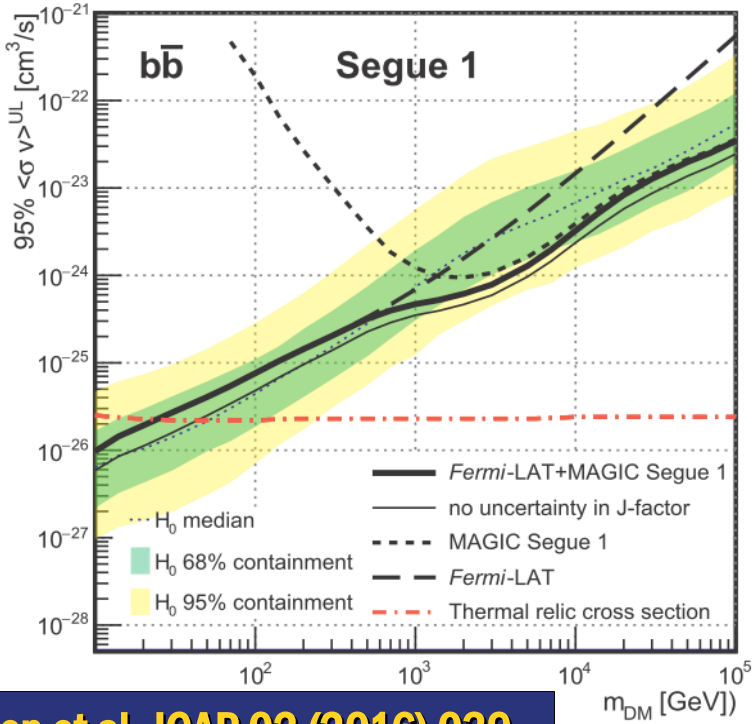
Dark Matter searches with MAGIC





- MAGIC can search for Gamma-ray signature of DM decay in suitable regions
- Observed Dwarf Spheroidal Galaxy Segue1 for 158 h **Aleksić et al.JCAP 02 (2014) 008**

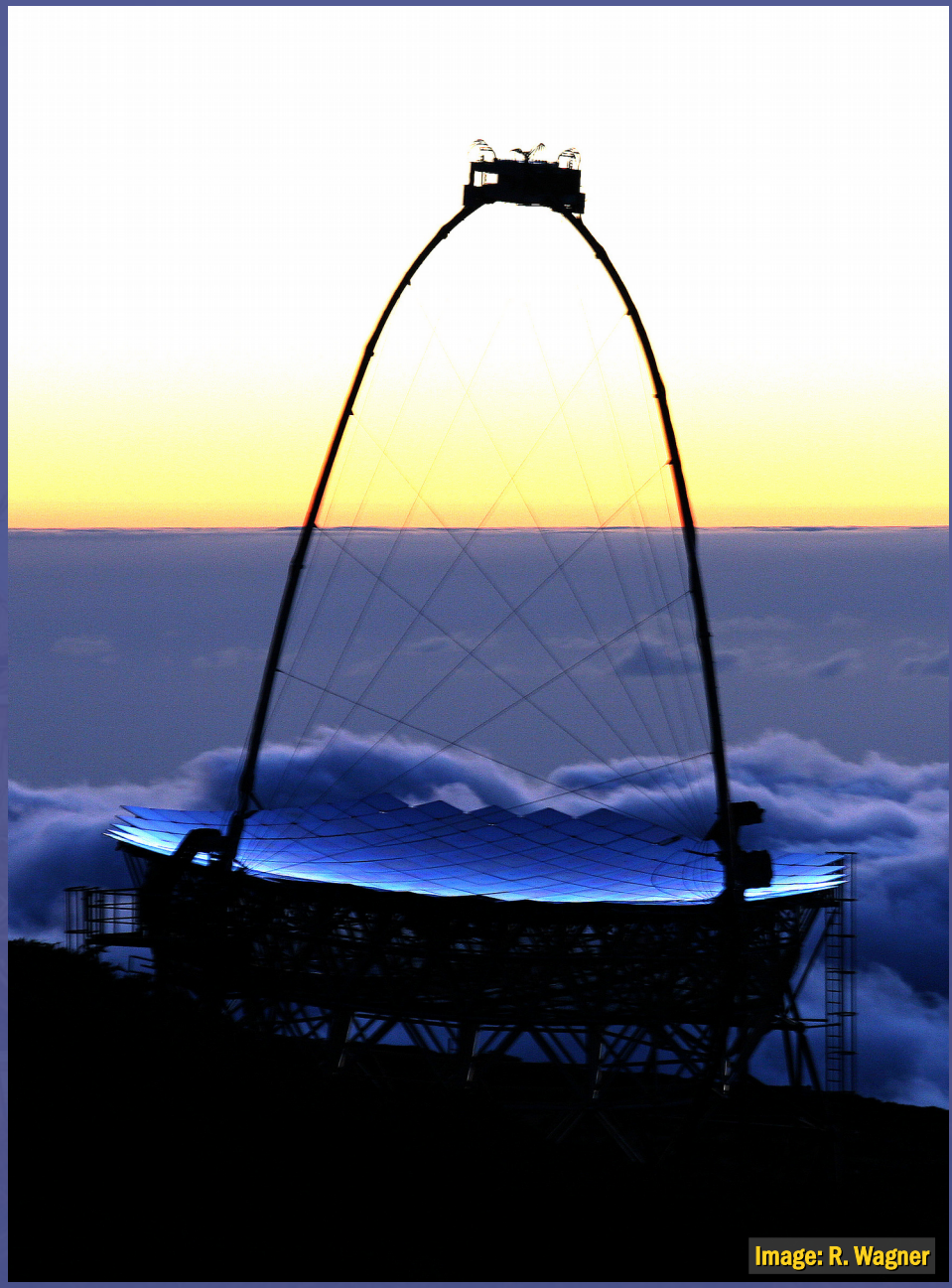
  → Limits together with Fermi cited by PDG
- Observed Perseus Cluster for over 250 h
- Also > 60h on Gal. Center



Ahnen et al. JCAP 02 (2016) 039

Conclusions:

- MAGIC is one of the most competitive instruments for TeV astrophysics
- Last few years were the most productive in terms of scientific output, no hint for turnover!

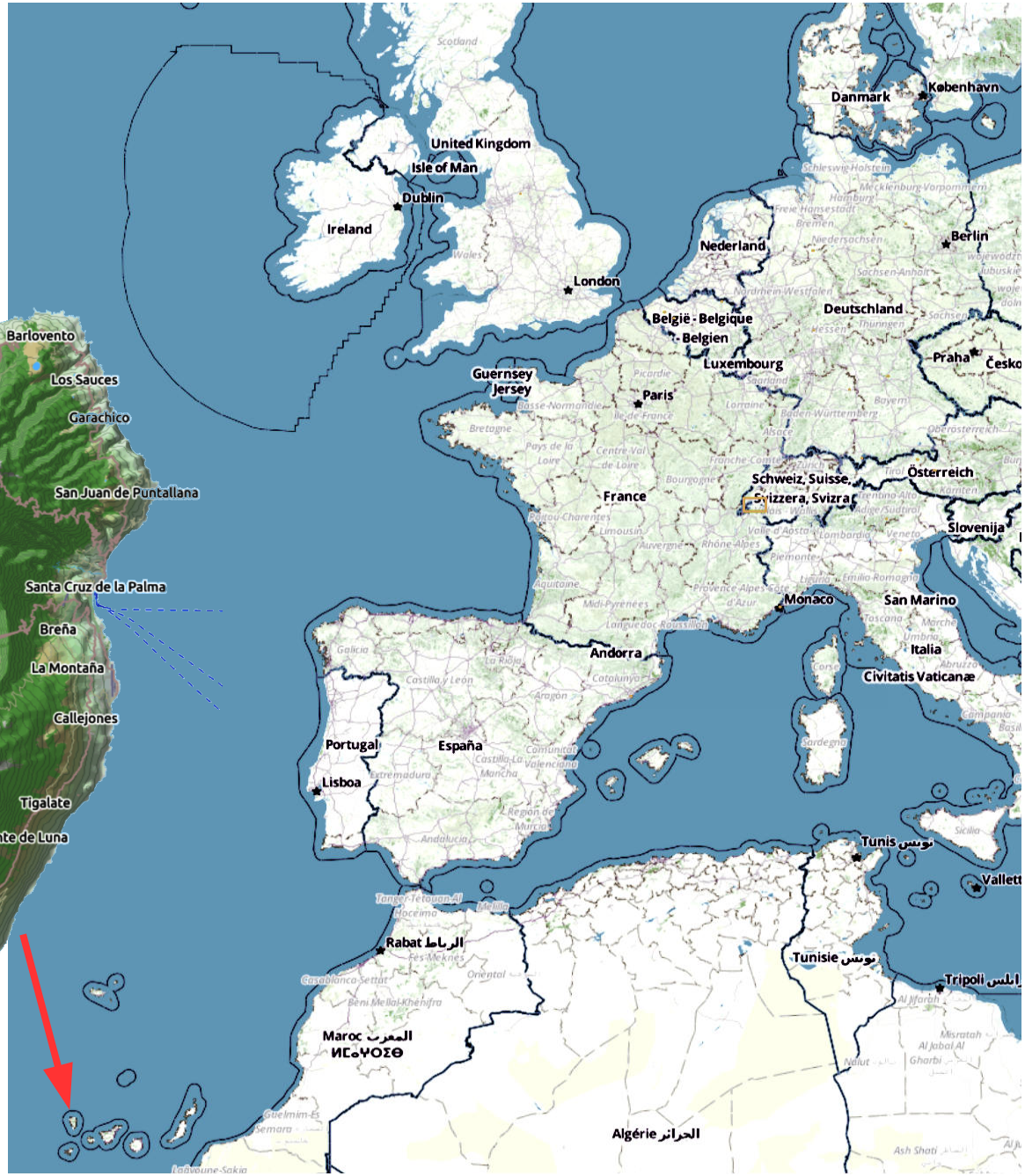


Backup

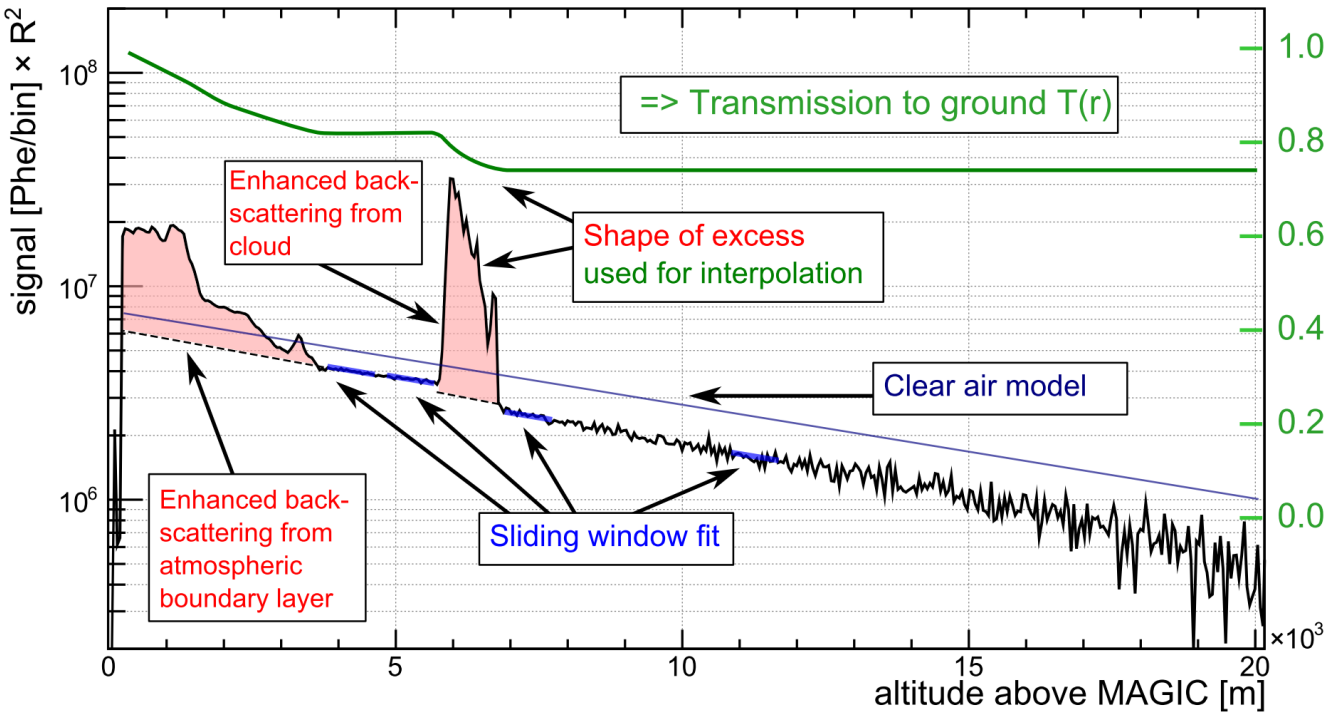
The MAGIC Telescopes on La Palma

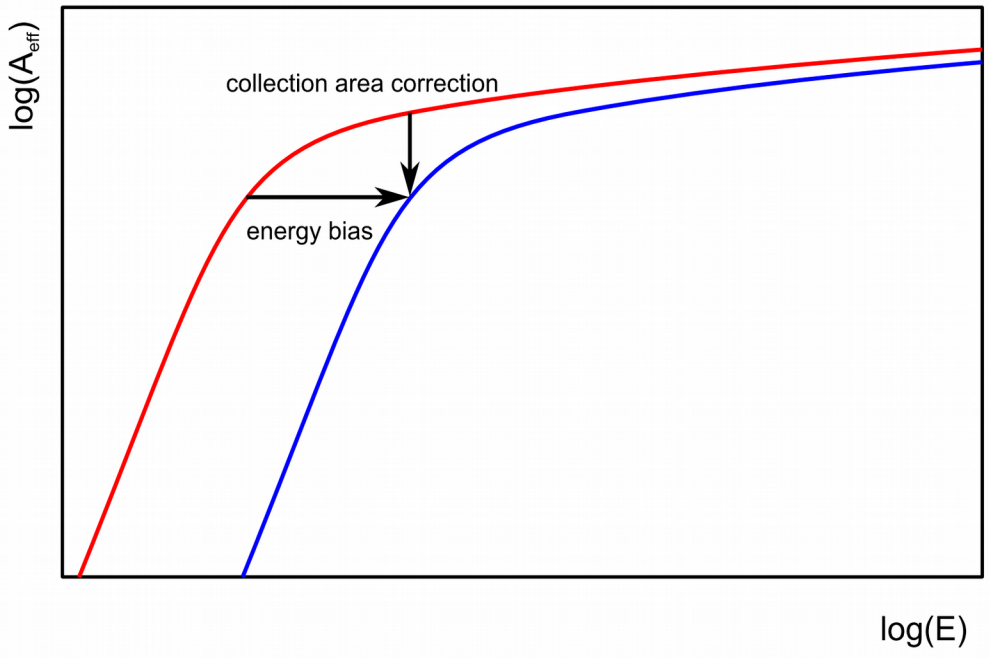
Site:

- Observatorio del Roque de los Muchachos
- 2200m a.s.l.
- La Palma
- Canary islands, Spain

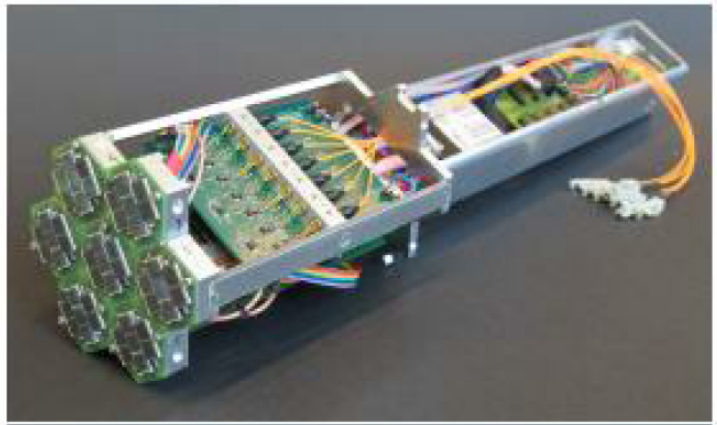


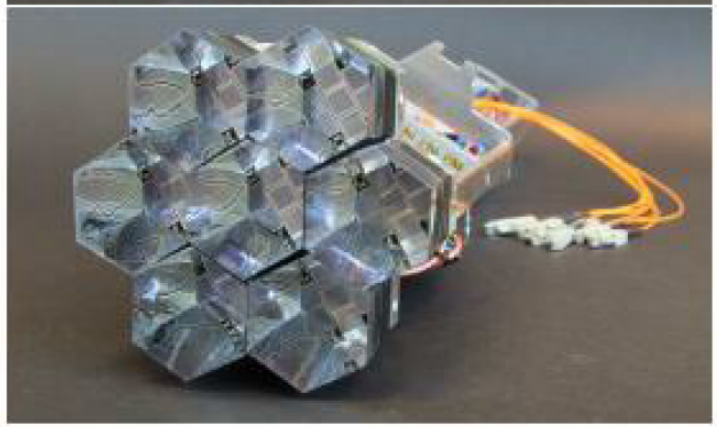
Backup: LIDAR method





MPP SiPM cluster in MAGIC-I camera





Achievements

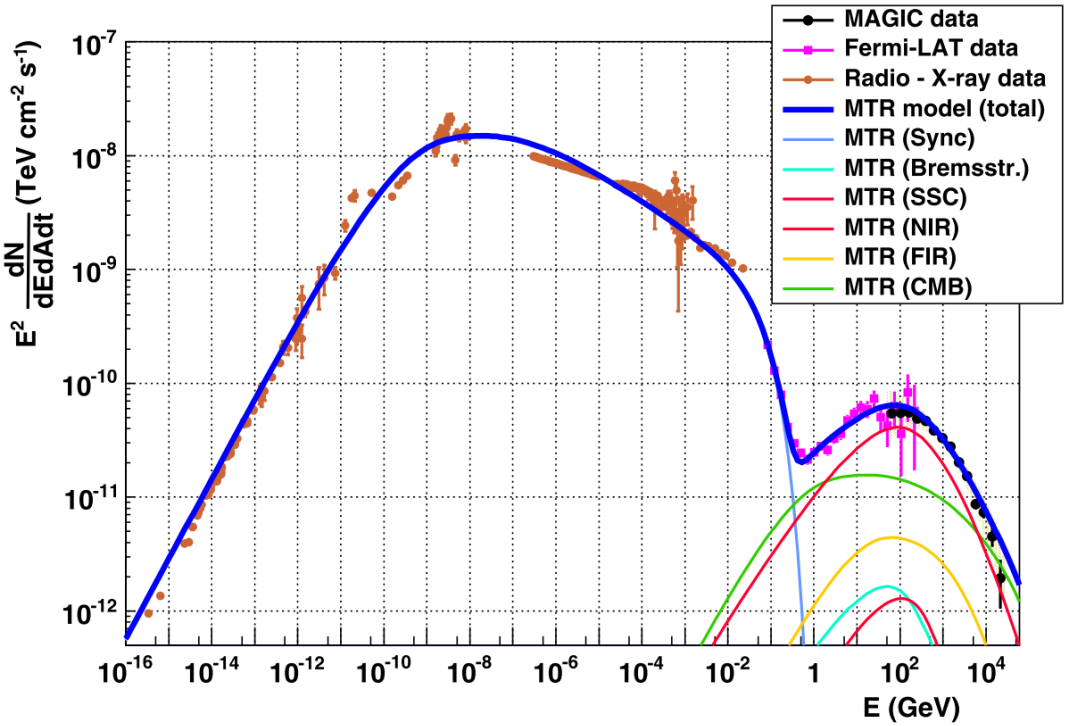
- Developed,
- Built,
- Tested,
- and Installed the first SiPM cluster
- Modified CaCo for controlling
- Cluster is running since July 2015
- Included in standard data taking

Future tasks

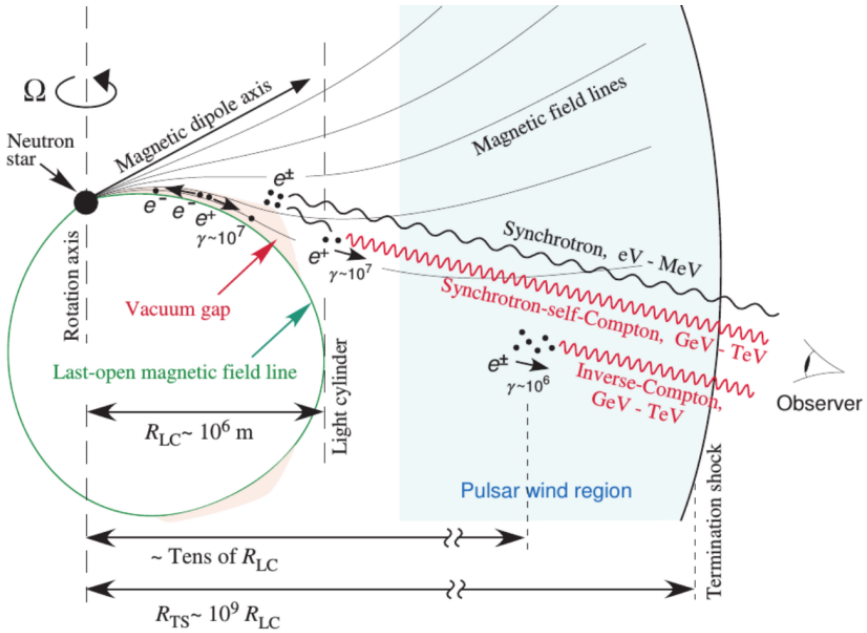
- Detailed comparison to PMT clusters
- Long-term stability test in MAGIC
- Characterize new SiPMs
- More Winston cone simulations and measurements
- Build two new prototype clusters
- ASIC approach with David Gascon et al. from the University of Barcelona

The Crab Nebula and Pulsar

- Remnant of the SN 1054 hosting Pulsar and PWN
- Brightest steady source of TeV emission in the sky
- Bright source over the whole EM spectrum
- MAGIC detects Nebula and pulsed component

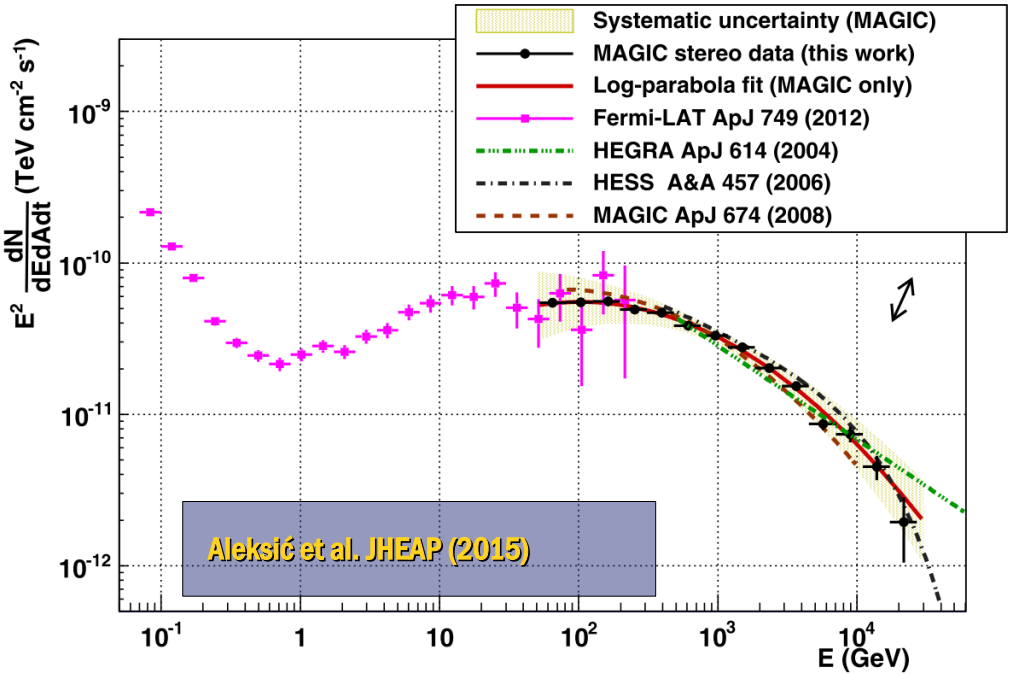


Aleksić et al. JHEAP (2015)

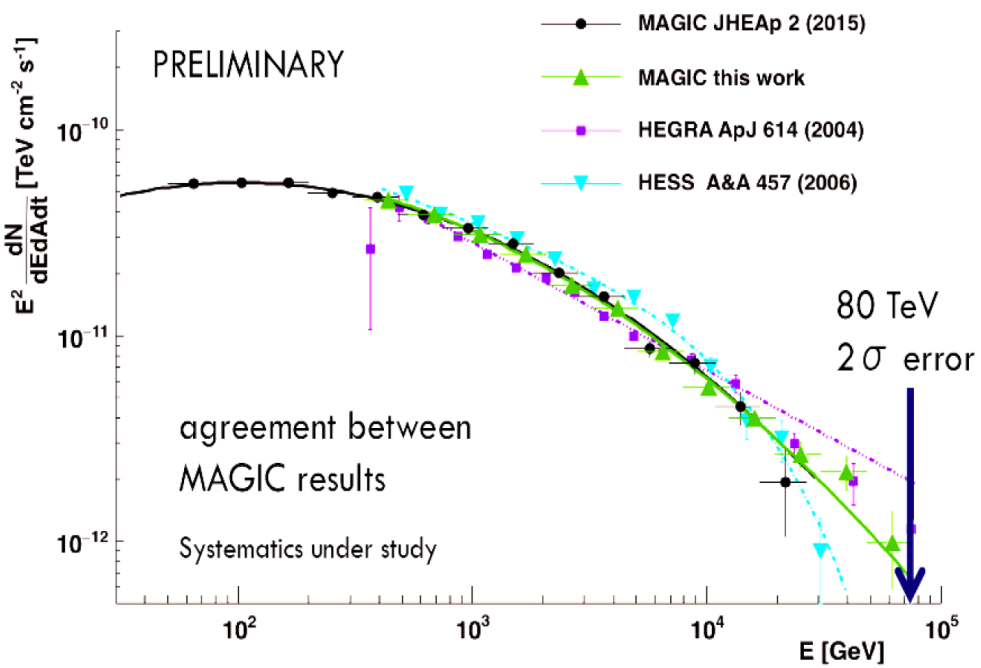


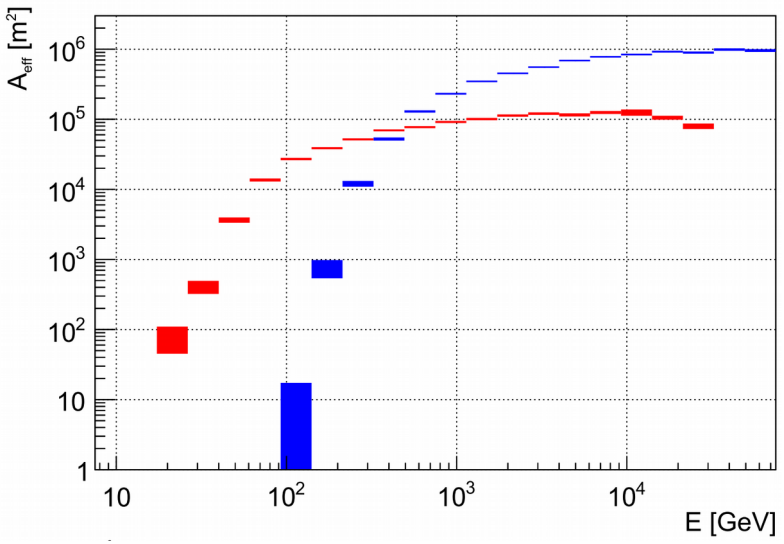
MAGIC observing Crab over 3 decades in energy

measuring Crab Nebula spectrum from 50 GeV to 30 TeV



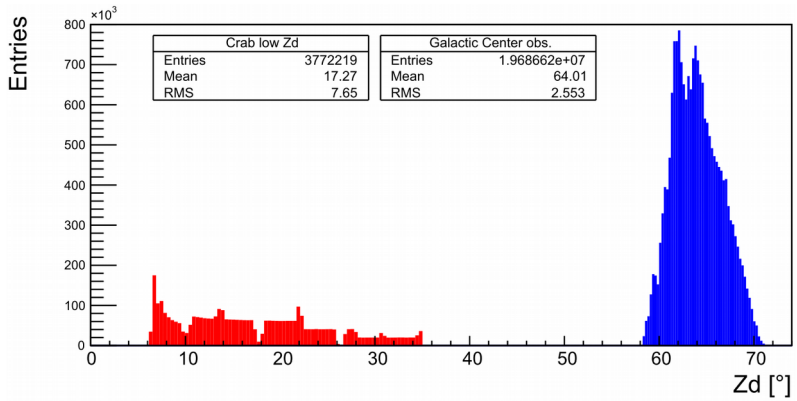
Can go even higher in energy using HZD observations





Zd = 5 – 35 deg

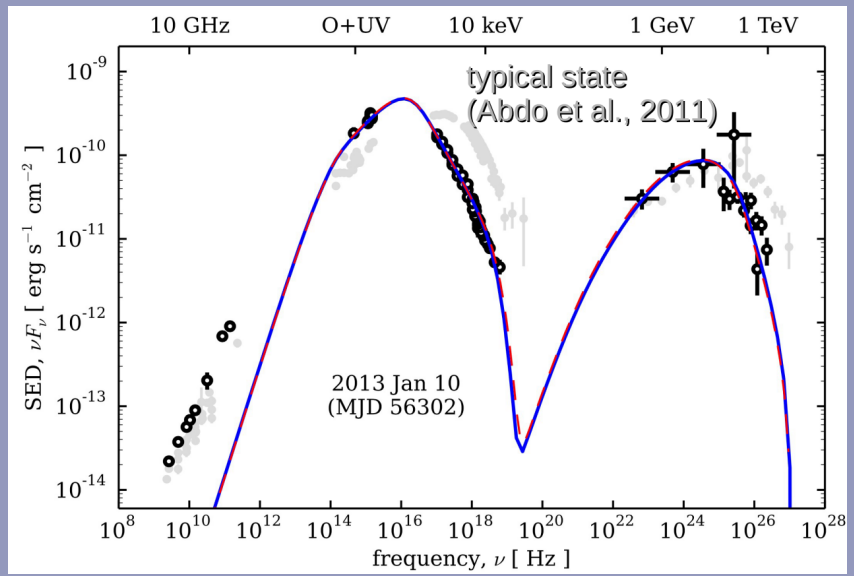
Zd = 60 – 70 deg



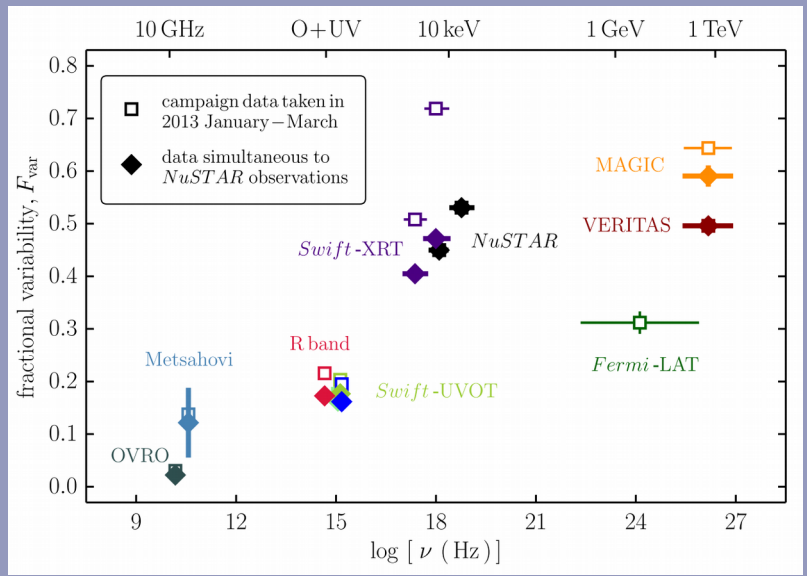
Bright Blazars – Mrk 421, Mrk 501

- MAGIC observed Gal. Center for 4 years (2012/13/14/15)
- Observations triggered by G2 gas cloud pericenter passage
- No flux variation observed in TeV regime (also no detection in other w.l.)
- Performed detailed spectral, temporal and morphological studies
- Discovered new source of VHE Gamma radiation coincident with GC Arc

SED of Mrk 421

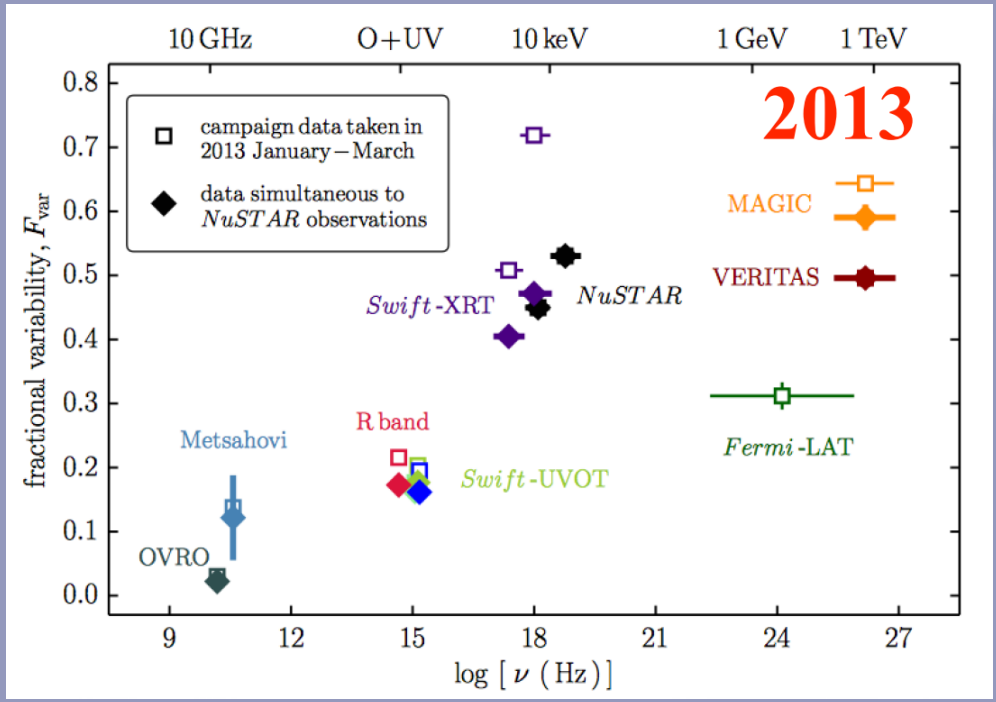


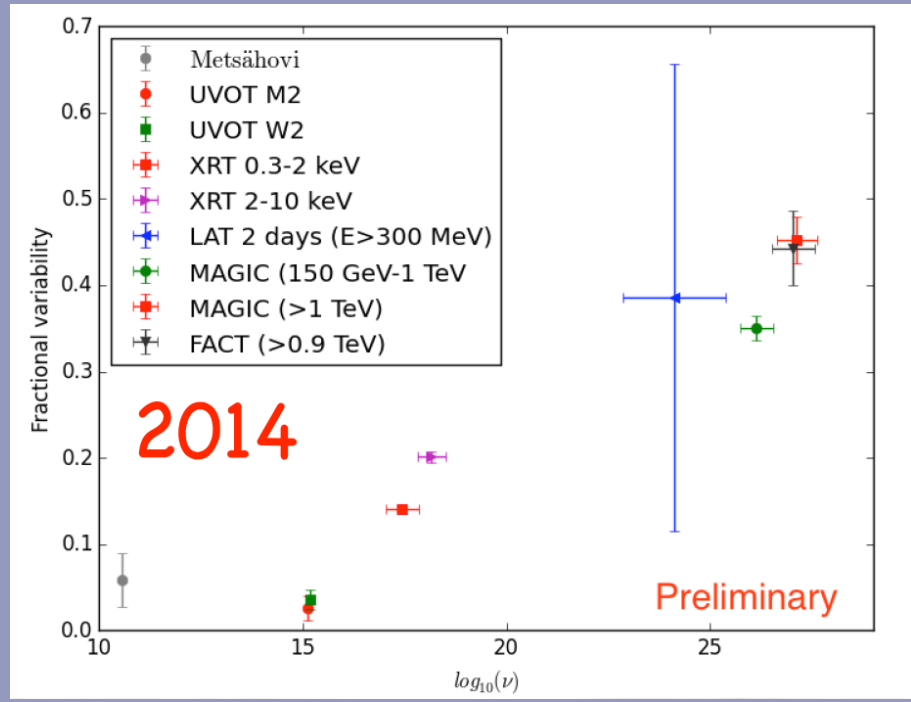
Fractional variability of Mrk 421



MWL observations of Mrk 421

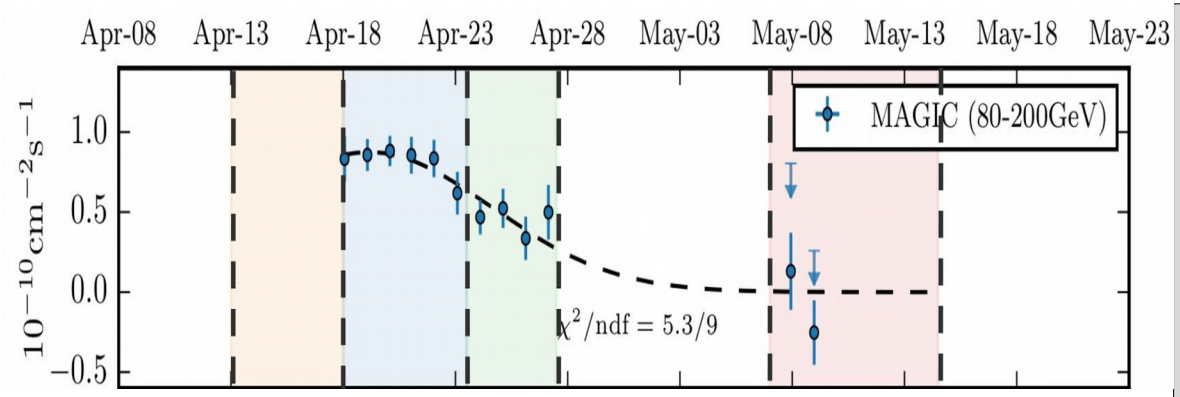
Fractional variability of Mrk 421in 2013/2014 flares



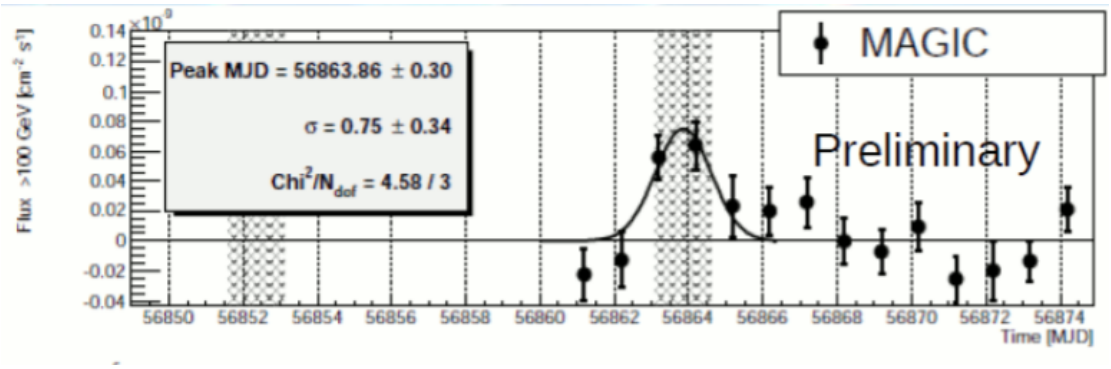


Highest energies vary most!

MAGIC detects two AGN at redshift ~1



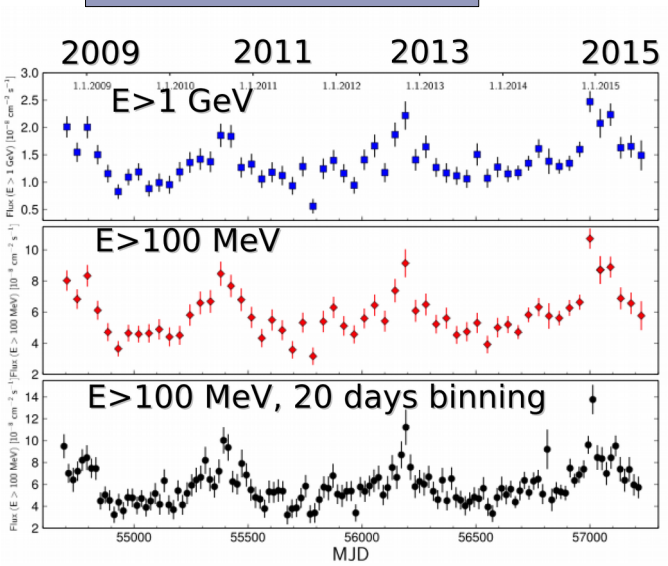
- MAGIC detected for the first time VHE emission from the z=0.940 Blazar PKS 1441+25 during a MWL outburst in April 2015.



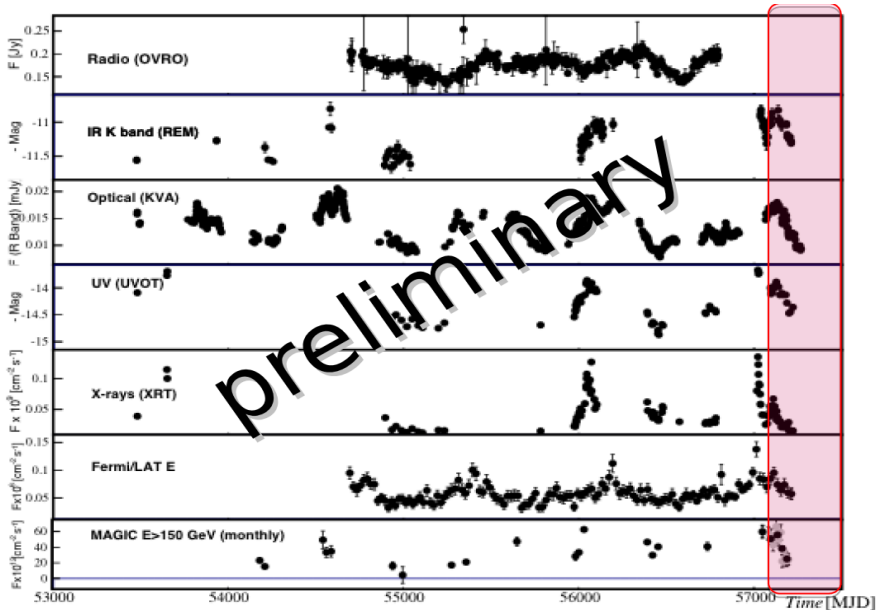
- QSO B0218+375: most distant blazar (z=0.944) detected so far in VHE gamma-rays, using MAGIC in only 2 hours of observations

Quasiperiodicity in PG 1553+113 ?

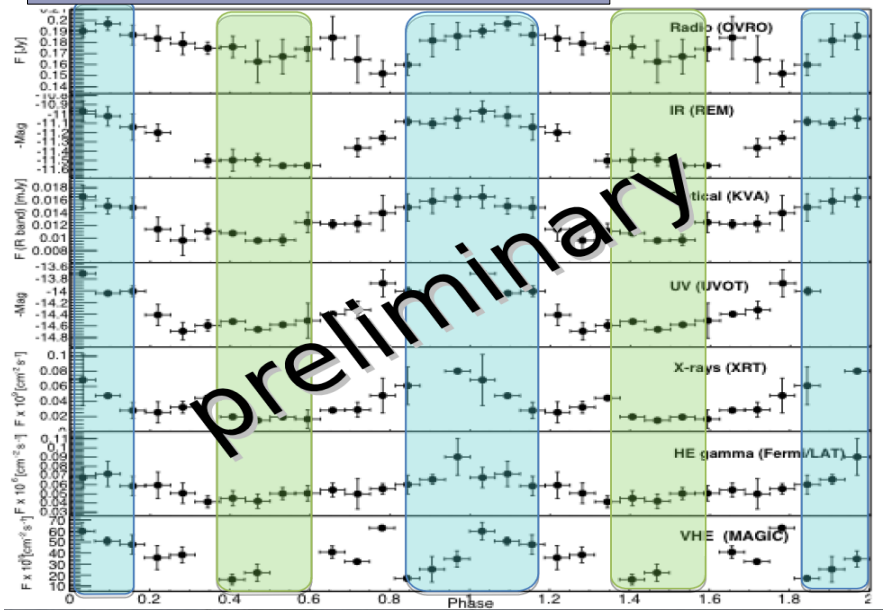
First hint in Fermi data



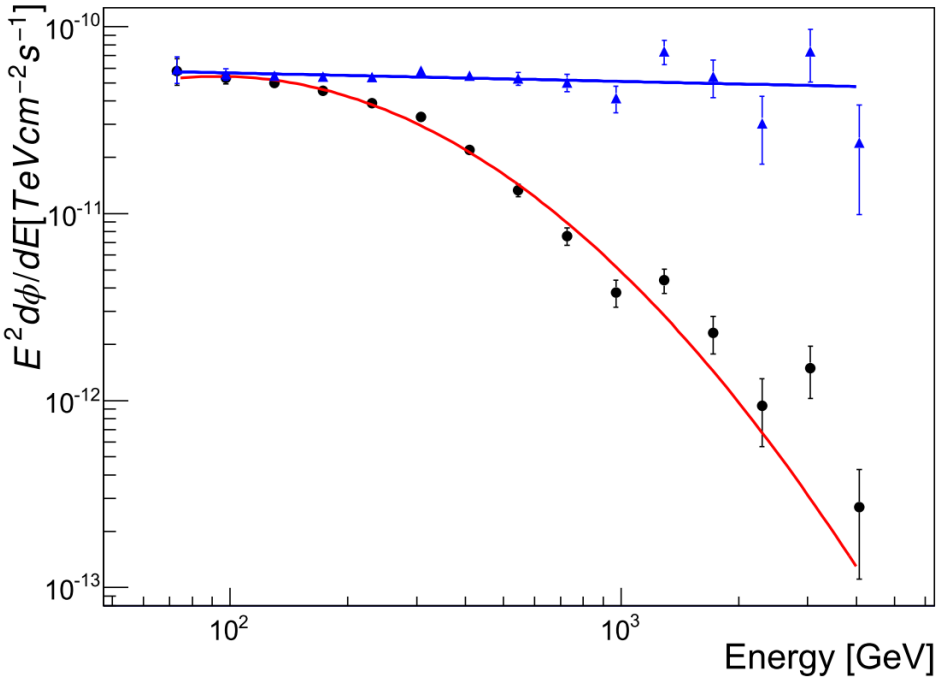
- Intense multi-wavelength and multi-year campaign led by MAGIC started in late 2014
- Currently we are sampling the minimum phase
- Maximum and and minimum phase visible at different wavelengths
- More data needed! (especially in UV; X-ray; VHE)



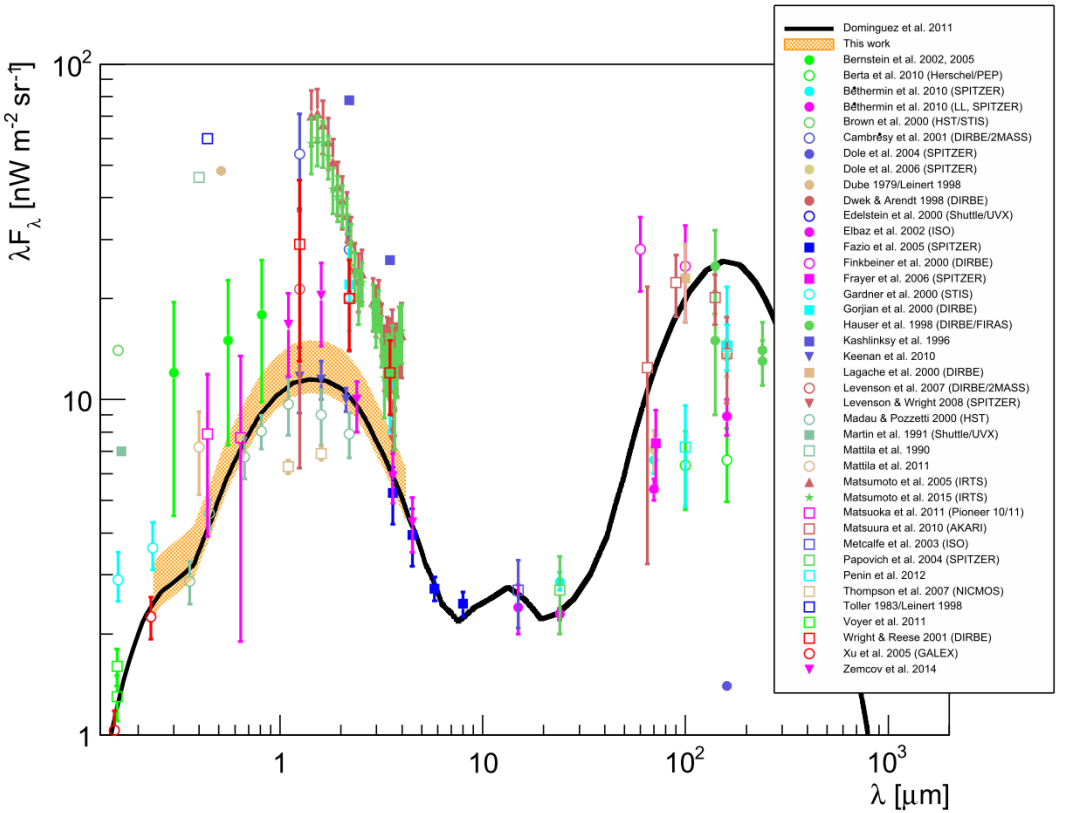
Light curve folded (with T = 798d)



EBL measuremens with MAGIC

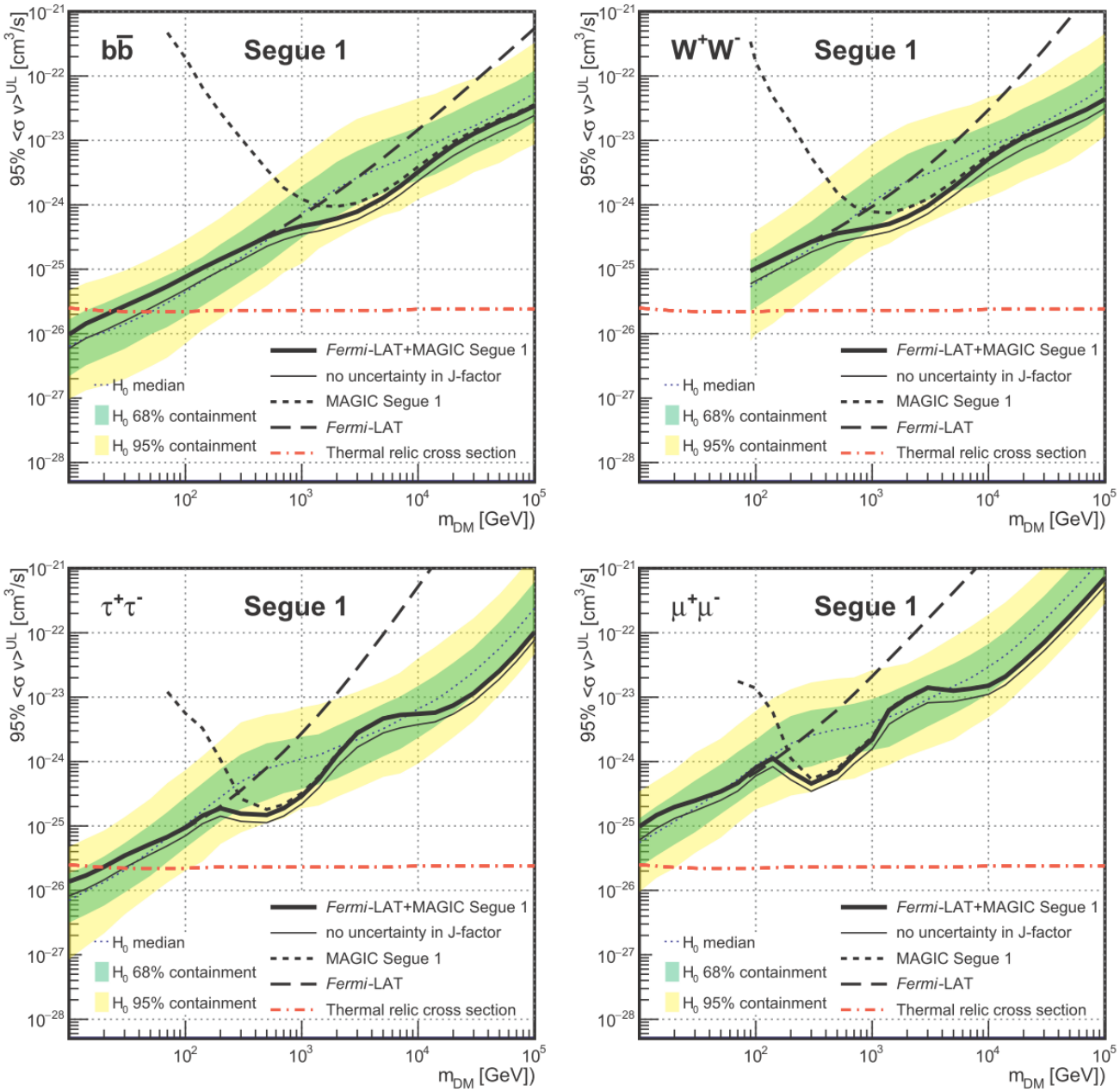


- VHE Gamma-rays get absorbed (cascaded) by photon-photon interaction with EBL on long dist.
- Information of the intrinsic spectral shape of distant sources can be used to measure EBL



Ansoldi et al. A&A submitted(2015)

Upper limits on DM decay in dwarf galaxy Segue1

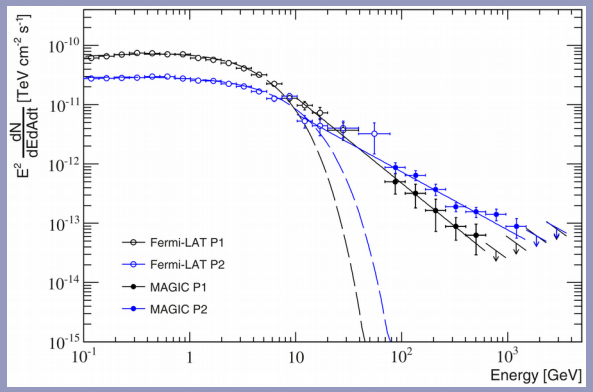


- Deep observations of the dwarf spheroidal Galaxy Segue1 by MAGIC (158h)
- Best ULs for DM annihilation cross-section from dSph in the high-mass range
- The results are acknowledged by in PDG

Ahnen et al. accepted in JCAP (2016) arXiv:1601.06590

The main scientific targets of MAGIC

Galactic Physics:
PWN, SNR, Binaries, Pulsars, Galactic Center



Ansoldi et al.
A&A 585,
A133 (2016)

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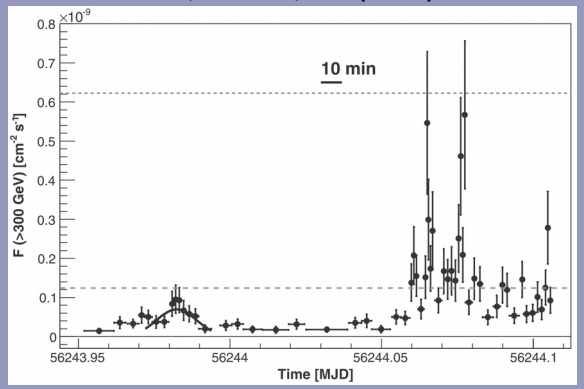
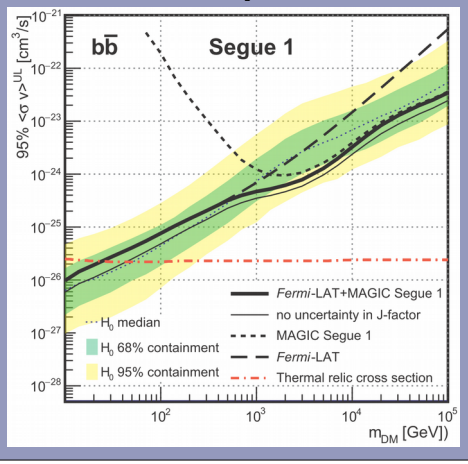
BL Lacs, FSRQs, Radio galaxies

Aleksić et al., Science, 346(2014) 1080 A



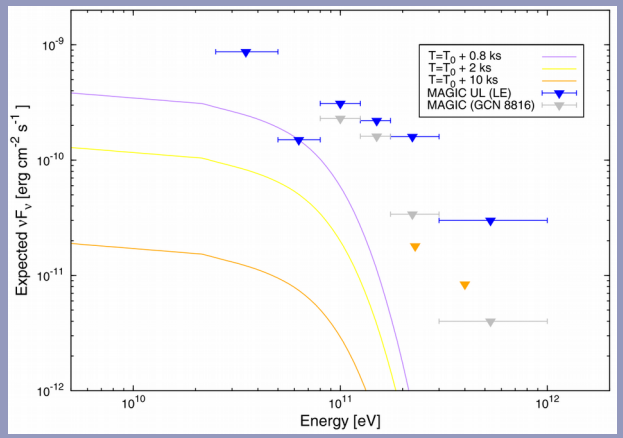
Fundamental Physics:
Dark matter, LIV, EBL, IGMF & cosmology



Ahnen et al.
accepted in JCAP (2016)
arXiv:1601.06590

Gamma Ray Bursts:

Aleksić et al.,MNRAS 437(2014)3103 A



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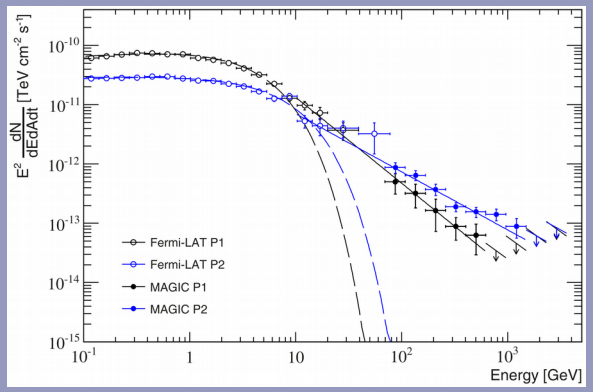

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A&A 585,
A133 (2016)

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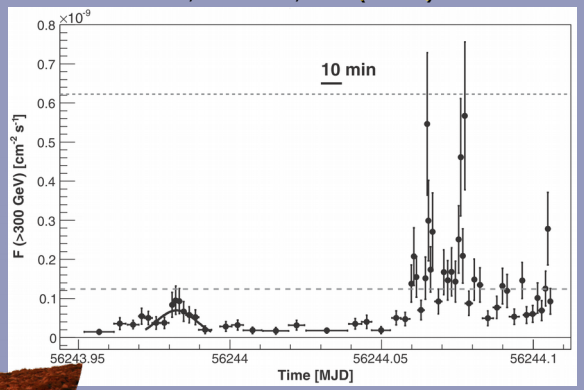
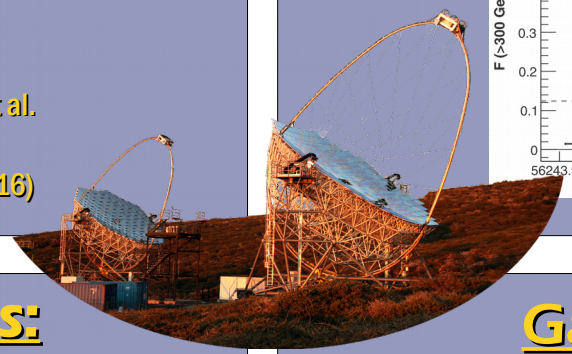
Aleksić et al., Science, 346(2014) 1080 A





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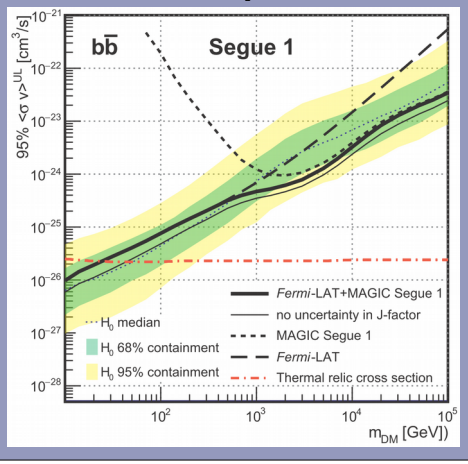

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